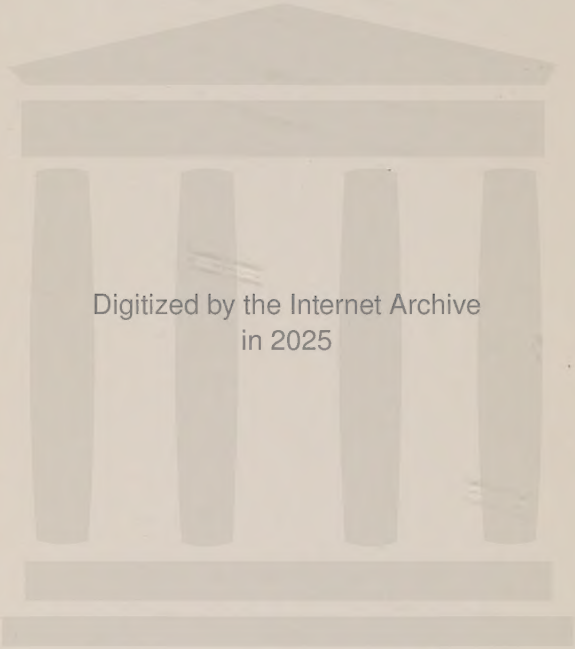
SCIENCE IN LITERATURE

Edited by

FREDERICK HOUK LAW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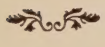
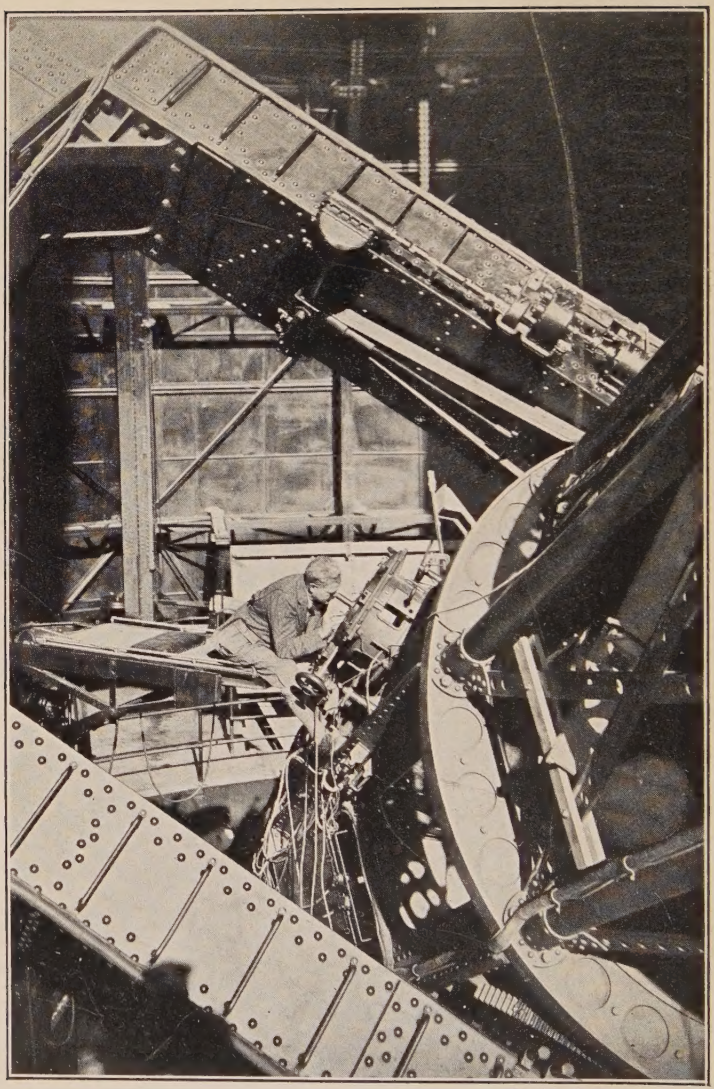
SCIENCE IN LITERATURE

A Collection of Literary Scientific Essays



"The popular conception of a scientist as a man who works in a laboratory and who uses instruments of precision is as inaccurate as it is superficial, for a scientist is known, not by his technical processes, but by his intellectual processes; and the essence of the scientific method of thought is that it proceeds in an orderly manner toward the establishment of a truth."

FRANCIS W. PEABODY



Ewing Galloway, N. Y.

THE GREAT TELESCOPE, MT. WILSON OBSERVATORY,
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A Bridge Across the Depths of Space

SCIENCE IN LITERATURE

A Collection of Literary Scientific Essays

Edited by

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PREFACE

"A COLLECTION of scientific writings (about 150 pages)" is called for by the College Entrance Requirements in English. It is to provide suitable material for that requirement, that this book has been prepared.

This is not a textbook in Science: it is a textbook in Literature. The subject matter concerns Science in various phases, but the method is the method of Literature, the method of inspiration, the method of wonder, of beauty, and even of awe.

The great adventures today are the adventures of Science. Once there was a time when men in ships or on foot explored the physical world. Today men explore the physical world in a new way, the way of Science, and they find greater regions to conquer, greater mysteries to explain, greater values to give to their fellow-men, than any found by the explorers of a former day.

In the times that succeeded Columbus and his companion voyagers, men throughout the civilized world felt the breath of a new life. Gallant companies set out in little ships, some to sail to the Indies; some to voyage around continents; some to reveal the riches of Cathay or Peru; some to seek the Fountain of Youth; some to look upon new seas that stretched invitingly away to no one knew where. Today those cruder adventurers have gone, and we rejoice in the lands that they opened for us at the cost of monotonous journeys, peril, and even of life. Today far more wonderful men are opening far more wonderful regions, but the men are Scientists who seek truth merely for the sake of truth, and the regions are all that

is, the world of life, the world of matter, the atoms and the stars.

The work of Science is the very breath of the present civilization. Long ago Literature pointed to the outward charms of mountains, flowers, birds, the sea, and the whole realm of nature, as well as to the tragedy, the comedy, and the spiritual growth of man. Today a new and rapidly growing type of Literature sets forth the work of our present daring adventurers, the men of Science. This new type of Literature enshrines the spirit of the present day. It fills the reader with the same zest for adventure that the people of old England, Spain, Italy, Portugal, and Holland, felt when they stood wondering at the reports of Columbus or Magellan, Pizarro or Cortez. If we ourselves can not adventure and be, as it were, colonists in the new lands of Science, we can at least read and learn what has been discovered. We can share the spirit of the day in which we live.

Who knows what the youth of today, if inspired by the deeper purposes of Science, the intense desire to know what is true, may yet accomplish for mankind!

Certainly the inspirational side of Science, not merely the mastering of fact and of laboratory detail, but the breathing in of the very spirit of scientific interest, has place in our present courses in schools and colleges.

It is one thing to be an inventor: it is another to be a Scientist, a lover of truth, keen in observation, patient in research, trying to understand more and more of the nature of all things.

The study of Science is linked eternally with Literature which, at its best, is the record of man's effort to understand his world and his fellow man. The great English poet, Tennyson, proclaimed this, for he wrote:

"Little flower—but if I could understand
What you are, root and all, and all in all,
I should know what God and man is."

The proper presentation of the essays in this book should do much to reveal the uplifting power, the creative force, of the new type of Literature, the combination of exact Science and literary method.

Frederick Houk Law

INTRODUCTION

WISE, indeed, is the inclusion of "A collection of scientific writings (about 150 pages)" in the College Entrance Requirements in English.

THE SCIENTIST DEEPLY AFFECTS DAILY LIFE

Science today holds a commanding position over the lives of men. Science gives the means of providing food and clothing; of erecting great buildings; of traveling on land and sea with both ease and speed; of flying through the air; of bringing light into dark places; of sending thought instantly from continent to continent; and of measuring the size and the speed of the stars. Not a day passes in which men of the civilized world do not depend, from morning until night, upon the products of Science, the Bringer of Health, Wealth, and Happiness. Not a year passes in which the boundaries of the uncivilized world do not contract under the influences of Science, the Opener and the Revealer. Under the touch of Science fever-stricken jungles become the healthful habitations of men, and the providers of blessings for all. Even the waste solitudes of the Polar Regions reveal their secrets to men armed with equipment provided by Science. More than all else, the peoples of the world, brought nearer to one another because of Science, tend more than ever before to become neighbors and friends. For the United States, Science is said to earn over $30,000,000,000 annually, or nearly one-half the national income. As a subject closely related to the most common practical needs of life Science indeed holds a high place, and there-

fore must enter intimately into the literature of the age, that is so largely an age of Science.

THE TRUE SCIENTIST IS A KIND OF POET

The true Scientists of today, the students of truth, are, in a very real sense, poets. On the wings of imagination, guided by the microscope, the telescope, the spectroscope, and all the amazing variety of marvellous instruments, the true Scientist sees before him worlds filled with wonders such as no poets of preceding ages could vision. How the imagination quivers before the stupendous marvels of astronomy, and before the equally stupendous marvels of the atom! Whirling worlds, order, and system, and mysteries beyond all explaining! Beside all this the subjects of the past are small in interest and in power to uplift the soul to that elevation of wonder and awe, that higher understanding, that made the poets revealers.

THE TRUE SCIENTIST IS A SEER

Above all else, the true Scientist is a Seeker of Knowledge. The one object that he has in view is to learn what is true. His constant search brings to light not only visible wonders that lie about us, but also invisible wonders, so that he becomes a Revealer, or, as the people of former days might have said, a Seer.

THE TRUE SCIENTIST IS A PROPHET

The true Scientist, likewise, is a Prophet, foreseeing a new day, preparing for it, and hastening its coming. Men hidden away in laboratories work patiently for long months and years merely to see, to learn, to understand, with no other thought than the great joy of learning. Others follow in their steps, and add their mites to the store of information. Then, sud-

denly, it seems, some ingenious worker finds that the seemingly useless information, gathered at the cost of so much patience and such length of time, can be applied to make life happier or more effective for human advantage, and there come to the world benefits, such as engines for a thousand purposes; the automobile; the telephone; the electric light; the radio; radium for the fight against cancer; antitoxins for the war with bacteria; and all the other multitudinous gifts to which Science leads.

The search for truth is a search that leads to unexpected results. Ultimate truth men may not hope to know, but the everlasting search leads to the benefit and the uplift of man.

THE SPIRIT OF SCIENCE IS THE SPIRIT OF LITERATURE

Science, then, is the very stuff of which Literature is made. It represents the deepest aspiration of man for ultimate truth, the groping reach toward what is eternal and changeless. It interprets life and reality as no mere abstract philosophy has ever been able to interpret them. It reveals the world in the deepness of its wonder, and in the fulness of its power. It awakens men to passionate interest in all things, from the grain of dust to the unbelievably enormous star. It leads the way to exact thought, to guaranteed conclusions, to a truth-founded appreciation of all things. It presents such a multiplicity of objects of beauty and of awe-inspiring power that it is at once the stimulator of the mind, and the awakener of the soul. It considers beauty in myriads of forms, and constantly reveals new beauty. It arouses new questions, new strivings, new and high endeavors to seek truth for truth's own sake. In all ways the Scientist today holds the place of Guide, Revealer, and Inspirer so long held by the poet. Science itself is indeed the very stuff of which Literature is made.

THE INSPIRATION OF SCIENCE SHOULD BE GAINED THROUGH THE LITERATURE OF SCIENCE

Something of the interest and wonder of this poetry of the present day should aid, not only in informing, but also in awakening and inspiring all who love the study of Literature, which itself is but a study of truth and of beauty.

THIS BOOK CONTAINS ONLY INSPIRATIONAL SCIENTIFIC ESSAYS

For that reason this book presents a series of essays written by men of Science, not dry expositions of scientific facts and problems, but inspirational essays written with the intent of clarifying observation and knowledge of the world about us; of arousing interest in the True, that is likewise the Beautiful; and of inspiring readers to try to enter into fellowship with the company of earnest seekers for truth.

It would have been easy to select a series of narratives concerning the lives of great Scientists; or a series of simple, popular explanations of fundamental scientific facts; or a series of simple accounts of the inventions of some of our most useful devices.

Such, however, would not fulfil the purpose of this book, which is not at all the presenting of facts, or the explanation of theories, but wholly the literary power, the driving force, the uplifting inspiration, of the words of scientific workers.

THE METHOD OF STUDY SHOULD BE COMPANIONABLE, AND SHOULD LEAD TO ORIGINAL OBSERVATION AND EXPERIMENT

The pupils should read the essays, endeavor as far as possible to understand the subject matter, master the vocabulary, notice the various writers' methods of presentation, plans of treatment, ways of arousing interest, use of devices that lead to

clearness, and their general literary skill, and above all, learn to sympathize with the purposes made evident in the essays.

If possible the pupils should try to carry into actual life, that is, into actual original observation and experiment, the principles presented.

In the classroom, teacher and pupils should discuss the essays along the lines suggested by the questions printed in connection with the various papers.

Last of all, teacher and pupils alike will find further reading in the literature of Science both delightful and stimulating. Lists of trustworthy, interesting books are given throughout this work.

All who use this book should bear in mind that the object is inspiration, not memorizing. A Gradgrind method of study should not be undertaken. Instead of the cold, hard, question and answer method, there should be companionable talk, interested discussion, and the awakening of creative interest in Science.

SECRET OF THE CHARM OF FLOWERS

By

WILLIAM HENRY HUDSON

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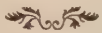

"All resemblances to man in the animal and vegetable worlds and in inanimate nature, enter largely into and strongly color our æsthetic feelings."

W. H. HUDSON.

WILLIAM HENRY HUDSON
(1841-1922)

Whoever has read *Green Mansions, The Purple Land,* or *Far Away and Long Ago,* has become a lover of William Henry Hudson, the distinguished British naturalist and author. In those delightful books the reader feels the presence of such a charming personality that he falls at once under the author's power of enchantment.

It is strange that so gifted a scientist and writer should have had to fight most of his life against adversity. Dogged by poverty and ill health, Mr. Hudson still kept the ability to look on the world with the eyes of a lover of nature, and the power to put into rich word music his observations and meditations, and all this in such a way as to leave his readers the better for having read.

In some ways Mr. Hudson's life was romance itself. Born near Buenos Aires, in the Argentine, he lived in the great world of outdoor life under the broad skies of the pampas, until he was 29. Then he went to England, where he continued his studies of nature, especially of birds, and wrote his books.

What better can be said of him than that, in his memory, his friends erected a Bird Sanctuary in Hyde Park, London?

Among Mr. Hudson's works are: *The Purple Land* (1885); *A Crystal Age* (1887); *British Birds* (1895); *El Ombu* (1902); *Green Mansions* (1904); *A Shepherd's Life* (1910); *Far Away and Long Ago* (1918); *Dead Man's Plack* (1920); *Birds of La Plata* (1920); *A Hind in Richmond Park* (1922).

SECRET OF THE CHARM OF FLOWERS

By William Henry Hudson

I. THE EFFECT OF HUMAN ASSOCIATIONS

WHEN my mind was occupied with the subject of the human quality in some sweet bird voices—it struck me forcibly that all resemblances to man in the animal and vegetable worlds and in inanimate nature, enter largely into and strongly color our æsthetic feelings. We have but to listen to the human tones in wind and water, and in animal voices; and to recognize the human shape in plant, and rock, and cloud, and in the round heads of certain mammals, like the seal; and the human expression in the eyes, and faces generally, of many mammals, birds and reptiles, to know that these casual resemblances are a great deal to us. They constitute the *expression* of numberless natural sights and sounds with which we are familiar, although in a majority of cases the resemblance being but slight, and to some one quality only, we are not conscious of the cause of the expression.

It was principally with flowers, which excite more attention and give more pleasure than most natural objects, that my mind was occupied in this connection; for here it seemed to me that the effect was similar to that produced on the mind by sweet human-like tones in bird music. In other words, a very great if not the principal charm of the flower was to be traced to the human associations of its coloring; and this was, in some cases, more than all its other attractions, including beauty of form, purity and brilliance of color, and the harmoni-

ous arrangement of colors; and, finally, fragrance, where such a quality existed.

We see, then, that there is an intimate connection between the two subjects—human associations in the coloring of flowers and in the voices of birds; and that in both cases this association constitutes, or is a principal element in, the *expression*. This connection, and the fact that the present subject was suggested and appeared almost an inevitable outcome of the one last discussed, must be my excuse for introducing a chapter on flowers in a book on birds—or birds and man. But an excuse is hardly needed. It must strike most readers that a great fault of books on birds is, that there is too much about birds in them, consequently that a chapter about something else, which has not exactly been dragged in, may come as a positive relief.

As the word expression which occurs with frequency in this chapter was not understood in the sense in which I used it on the first appearance of the book, it may be well to explain that it is not used here in its ordinary meaning as the quality in a face, or picture, or any work of art, which indicates thought or feeling. Here the word has the meaning given to it by writers on the æsthetic sense as descriptive of the quality imparted to an object by its associations. These may be untraceable: we may not be conscious and as a rule we are not conscious that any such associations exist; nevertheless they are in us all the time, and with what they add to an object may enhance and even double its intrinsic beauty and charm.

2. ASSOCIATIONS WITH BLUE

I have somewhere read a very ancient legend, which tells that man was originally made of many materials, and that at the last a bunch of wild flowers was gathered and thrown into the mixture to give color to his eyes. It is a pretty story, but

might have been better told, since it is certain that flowers which have delicate and beautiful flesh-tints are attractive mainly on that account, just as blue and some purples delight us chiefly because of their associations with the human iris. The skin, too, needed some beautiful color, and there were red as well as blue flowers in the bunch; and the red flowers being most abundant in nature and in greater variety of tints, give us altogether more pleasure than their beautiful rivals in our affection.

The blue flower is associated, consciously or not, with the human blue eye; and as the floral blue is in all or nearly all instances pure and beautiful, it is like the most beautiful human eye. This association, and not the color itself, strikes me as the true cause of the superior attraction which the blue flower has for most of us. Apart from association blue is less attractive than red, orange, and yellow, because less luminous; furthermore green is the least effective background for such a color as blue in so small an object as a flower; and, as a fact, we see that at a little distance the blue of the flower is absorbed and disappears in the surrounding green, while reds and yellows keep their splendor. Nevertheless, the blue has a stronger hold on our affections. As a human color, blue comes first in a blue-eyed race because it is the color of the most important feature, and, we may say, of the very soul in man.

Some purple flowers stand next in our regard on account of their nearness in color to the pure blue. The wild hyacinth, blue-bottle, violet, and pansy, and some others, will occur to every one. These are the purple flowers in which blue predominates, and on that account have the same expression as the blue. The purples in which red predominates are akin in expression to the reds, and are associated with flesh-tints and blood. And here it may be noted that the blue and blue-purple

flowers, which have the greatest charm for us, are those in which not only the color of the eye but some resemblance in their form to the iris, with its central spot representing the pupil, appears. For example, the flax, borage, blue geranium, periwinkle, forget-me-not, speedwell, pansy and blue pimpernel, are actually more to us than some larger and handsomer blue flowers, such as the blue-bottle, vipers' bugloss, and succory, and of blue flowers seen in masses.

With regard to the numerous blue and purple-blue flowers which we all admire, or rather for which we all feel so great an affection, we find that in many cases their very names have been suggested by their human associations—by their *expression.*

Love-in-a-mist, angels' eyes, forget-me-not, and heartsease, are familiar examples. Heartsease and pansy both strike us as peculiarly appropriate to one of our commonest and most universal garden flowers; yet we see something besides the sympathetic and restful expression which suggested these names in this flower—a certain suggestion of demureness, in fact, reminding those who have seen Guido's [1] picture of the "Adoration of the Virgin," of one of his loveliest angels whose angelical eyes and face reveal some desire for admiration and love in the spectator. And that expression, too, of the pansy named Love-in-Idleness, has been described, coarsely or rudely it may be, in some of its country names: "Kiss me behind the garden gate," and, better (or worse) still, "Meet-her-i'-th'-entry-kiss-her-i'-th'-buttery." Of this order of names are None-so-pretty and Pretty Maids, Pretty Betsy, Kiss-me-quick. Even such a name as Tears of the Blood of Christ does not sound extravagantly fanciful or startling when we look at the glowing deep golden crimson of the wall flower; nor of a blue flower, the

[1] Guido Reni (1575-1642). A great Italian painter.

germander speedwell, such names as The more I see you the more I love you, and Angel's Tears, and Tears of Christ, with many more.

A writer on our wild flowers, in speaking of their vernacular names of this kind, has said: "Could we penetrate to the original suggestive idea that called forth its name, it would bring valuable information about the first openings of the human mind towards nature; and the merest dream of such a discovery invests with a strange charm the words that could tell, if we could understand, so much of the forgotten infancy of the human race."

What a roll of words and what a mighty and mysterious business is here made of a very simple little matter! It is a charming example of the strange helplessness, not to say imbecility, which affects most of those who have been trained in our mind-killing schools; trained not to think, but taught to go for anything and everything they desire to know to the books. If the books in the British Museum [2] fail to say why our ancestors hundreds of years ago named a flower None-so-pretty or Love-in-a-mist, why then we must be satisfied to sit in thick darkness with regard to this matter until some heaven-born genius descends to illuminate us! Yet I daresay there is not a country child who does not occasionally invent a name for some plant or creature which has attracted his attention; and in many cases the child's new name is suggested by some human association in the object—some resemblance to be seen in form or color or sound. Not books but the light of nature, the experience of our own early years, the look which no person not blinded by reading can fail to see in a flower, is sufficient to reveal all this hidden wonderful knowledge about the first

[2] British Museum. A great museum in London, England, founded in 1753. Its library, the largest in the world, contains over 5,000,000 titles.

openings of the heart towards nature, during the remote infancy of the human race.

3. ASSOCIATIONS WITH RED

From this it will be seen that I am not claiming a discovery; that what I have called a secret of the charm of flowers is a secret known to every man, woman, and child, even to those of my own friends who stoutly deny that they have any such knowledge. But I think it is best known to children. What I am here doing is merely to bring together and put in form certain more or less vague thoughts and feelings which I (and therefore all of us) have about flowers; and it is a small matter, but it happens to be one which no person has hitherto attempted.

It may be that in some of my readers' minds—those who, like the sceptical friends I have mentioned, are not distinctly conscious of the cause or secret of the expression of a flower—some doubt may still remain after what has been said of the blue and purple-blue blossom. Such a doubt ought to disappear when the reds are considered, and when it is found that the expression peculiar to red flowers varies infinitely in degree, and is always greatest in those shades of the color which come nearest to the most beautiful flesh-tints.

When I say "beautiful flesh-tints" I am thinking of the æsthetic pleasure which we receive from the expression, the associations, of the red flower. The expression which delights is in the soft and delicate shades; and in the texture which is sometimes like the beautiful soft skin; but the *expression* would exist still in the case of floral tints resembling the unpleasant reds, or the reds which disgust us, in the human face. And we most of us know that these distressing hues are to be seen in some flowers. I remember that I once went into a florist's

shop, and seeing a great mass of hard purple-red cinerarias on a shelf I made some remark about them. "Yes, are they not beautiful?" said the woman in the shop. "No, I loathe the sight of them," I returned. "So do I!" she said very quickly, and then added that she called them beautiful because she had to sell them. She, too, had no doubt seen that same purple-red color in the evil flower called "grog-blossom," and in the faces of many middle-aged lovers of the bottle, male and female, who would perish before their time, to the great relief of their kindred, and whose actions after they were gone would not smell sweet and blossom in the dust.

The reds we like best in flowers are the delicate roseate and pinky shades; they are more to us than the purest and most luminous tints. And here, as with bird notes which delight us on account of their resemblance to fresh, young, highly musical human voices, flowers please us best when they exhibit the loveliest human tints—the apple blossom and the bindweed, musk mallow and almond and wild rose, for example. After these we are most taken with the deeper but soft and not too luminous reds—the red which we admire in the red horse-chestnut blossom, and many other flowers, down to the minute pimpernel. Next come the intense rosy reds seen in the herb-robert, and other wild geraniums, valerian, red campion and ragged robin; and this shade of red, intensified but still soft, is seen in the willow-herb and fox-glove, and, still more intensified, in the bell- and small-leafed heath. Some if not all of these pleasing reds have purple in them, and there are very many distinctly purple flowers that appeal to us in the same way that red flowers do, receiving their expression from the same cause. There is some purple color in most skins, and even some blue.

The azured harebell, like thy veins,

is a familiar verse from *Cymbeline;*[3] any one can see the resemblance to the pale blue of that admired and loved blossom in the blue veins of any person with a delicate skin. Purples and purplish reds in masses are mostly seen in young persons of delicate skins and high color in frosty weather in winter, when the eyes sparkle and the face glows with the happy sensations natural to the young and healthy during and after outdoor exercise. The skin purples and purple-reds here described are beautiful, and may be matched to a nicety in many flowers; the human purple may be seen (to name a very common wild flower) in purple loosestrife and the large marsh mallow, and in dozens and scores of other familiar purple flowers; and the purple-red hue in many richly colored skins has its exact shade in common hounds' tongue, and in other dark and purple-red flowers. But we always find, I fancy, that the expression due to human association in a purple flower is greatest when this color (as in the human face) is placed side by side with or fades into some shade of red or pink. I think we may see this even in a small flower like the fumitory, in which one portion is deep purple and all the rest of the blossoms a delicate pink. Even when the red is very intense, as in the common field poppy, the pleasing expression of purple on red is very evident.

To return to pure reds. We may say that just as purples in flowers look best, or have a greater degree of expression, when appearing in or with reds, so do the most delicate rose and pink shades appeal most to us when they appear as a tinge or blush on white flowers. Probably the flower that gives the most pleasure on account of its beautiful flesh-tints of different shades is the Gloire de Dijon rose, so common with us and so universal a favorite. Roses, being mostly of the

[3] *Cymbeline.* A delightful semi-historical play by Shakespeare. It concerns a legendary king of Britain.

garden, are out of my line, but they are certainly glorious to look at—glorious because of their associations, their expression, whether we know it or not. One can forgive Thomas Carew [4] the conceit in his lines—

> Ask me no more where Jove bestows
> When June is past, the fading rose,
> For in your beauty's orient deep
> These flowers as in their causes sleep.

But all reds have something human, even the most luminous scarlets and crimsons—the scarlet verbena, the poppy, our garden geraniums, etc.—although in intensity they so greatly surpass the brightest color of the lips and the most vivid blush on the cheek. Luminous reds are not, however, confined to lips and cheeks: even the fingers when held up before the eyes to the sun or to firelight show a very delicate and beautiful red; and this same brilliant floral hue is seen at times in the membrane of the ear. It is, in fact, the color of blood, and that bright fluid, which is the life, and is often spilt, comes very much into the human associations of flowers. The Persian poet,[5] whose name is best left unwritten, since from hearing it too often most persons are now sick and tired of it, has said,

> I sometimes think that never blooms so red
> The rose as where some buried Cæsar bled.

There is many and many a "plant of the blood of men." Our most common Love-lies-bleeding with its "dropping wells" of crimson serves to remind us that there are numberless vulgar names that express this resemblance and association. The thought or fancy is found everywhere in poetic literature, in

[4] Thomas Carew (1598-1639?). An English poet.

[5] The Persian Poet. Omar Khayyám, a twelfth century Persian poet, noted for the *Rubáiyát,* a remarkable poem well translated into English by Edward Fitzgerald (1809-1883).

the fables of antiquity, in the tales and folk-lore of all nations, civilized and barbarous.

4. ASSOCIATIONS WITH WHITE AND YELLOW

I think that we can more quickly recognize this human interest in a flower, due to its color, and best appreciate its æsthetic value from this cause, when we turn from the blues, purples, and reds, to the whites and the yellows. The feeling these last give us is distinctly different in character from that produced by the others. They are not like us, nor like any living sentient thing we are related to: there is no kinship, no human quality.

When I say "no kinship, no human quality," I refer to flowers that are entirely pure white or pure yellow; in some dull or impure yellows, and in white and yellow flowers that have some tinge or mixture of red or purple, we do get the expression of the red and purple flower. The crystalline and snow white of the whitest flowers do indeed resemble the white of the eyeballs and the teeth in human faces; but we may see that this human white color by itself has no human association in a flower.

The whiteness of the white flower where there is any red is never unhuman, probably because a very brilliant red or rose color on some delicate skins causes the light flesh-tints to appear white by contrast, and is the complexion known as "milk and roses." The apple-blossom is a beautiful example, and the beloved daisy—the "wee, modest, crimson-tipped flower," [6] which would be so much less dear but for that touch of human crimson. This is the herb-Margaret of so many tender and pretty legends, that has white for purity and red for repentance.

[6] "Wee, modest, crimson-tipped flower." A line from "To a Mountain Daisy" by Robert Burns (1759-1796).

Even those who have never read these legends and that prettiest, most pathetic of all which tells of the daisy's origin,[7] find a secret charm in the flower. Among other common examples are the rosy-white hawthorn, wood anemone, bindweed, dropwort, and many others. In the dropwort the rosy buds are seen among the creamy white open flowers; and the expression is always very marked and beautiful when there is any red or purple tinge or blush on cream-whites and ivory-whites. When we look from the dropwort to its nearest relative, the common meadow-sweet, we see how great a charm the touch of rose-red has given to the first: the meadow-sweet has no expression of the kind we are considering—no human association.

In pure yellow flowers, as in pure white, human interest is wanting. It is true that yellow is a human color, since in the hair we find yellows of different shades—it is a pity that we cannot find, or have not found, a better word than "shades" for the specific differences of a color. There is the so-called tow, the tawny, the bronze, the simple yellow, and the golden, which includes many varieties, and the hair called carroty. But none of these has the flower yellow. Richard Jefferies[8] tells us that when he placed a sovereign by the side of a dandelion he saw how unlike the two colors were—that, in fact, no two colors could seem more unlike than the yellow of gold and the yellow of the flower. It is not necessary to set a lock of hair and any yellow flower side by side to know how utterly different the hues are. The yellow of the hair is like that of

[7] The daisy's origin. According to a Roman legend, a dryad, who had been seen dancing on a meadow, was pursued by the god of Spring, and changed into a daisy by a friendly god who wished to help her. According to an early Christian legend the daisy is named for St. Margaret, who had been driven from home by her father, a heathen priest. Like her, the flower turns to heaven.

[8] John Richard Jefferies (1848-1887). An English naturalist, author of *Field and Hedgerow.*

metals, of clay, of stone, and of various earthly substances, and like the fur of some mammals, and like xanthophyll in leaf and stalk, and the yellow sometimes seen in clouds. When Ossian,[9] in his famous address to the sun, speaks of his yellow hair floating on the eastern clouds, we instantly feel the truth as well as beauty of the simile. We admire the yellow flower for the purity and brilliance of its color, just as we admire some bird notes solely for the purity and brightness of the sound, however unlike the human voice they may be. We also admire it in many instances for the exquisite beauty of its form, and the beauty of the contrast of pure yellow and deep green, as in the yellow flag, mimulus, and numerous other plants. But however much we may admire, we do not experience that intimate and tender feeling which the blues and reds inspire in us; in other words, the yellow flower has not the expression which distinguishes those of other colors. Thus, when Tennyson[10] speaks of the "speedwell's darling blue," we know that he is right—that he expresses a feeling about this flower common to all of us; but no poet would make so great, so absurd a mistake as to describe the purest and loveliest yellow of the most prized and familiar wild flower—buttercup or kingcup, yellow flag, sea poppy, marsh marigold, or broom, or furze, or rockrose, let us say—by such a word—the word that denotes an intimate and affectionate feeling—the feeling one cherishes for the loved ones of our kind. Nor could that word of Tennyson be properly used of any pure white flower—the stitchwort for instance; nor of any white and yellow flower like the Marguerite. But no sooner do you get a touch of rose or crimson in the whitest flower, as we see in the daisy and eyebright, than

[9] Ossian. A third century Gaelic bard and hero to whom James Macpherson (1736-1796) ascribed many poems.

[10] Alfred, Lord Tennyson (1809-1892). A great English poet laureate.

you can say of it that it is a "dear" or a "darling" color, and no one can find fault with the expression.

When we consider the dull and impure yellows sometimes seen in flowers, and some soft yellows seen in combination with pleasing wholesome reds, as in the honeysuckle, we may find something of the expression—the human association—in yellow flowers. For there *is* yellow in the skin, even in perfect health; it appears strongest on the neck, and spread round to the throat and chin, and is a warm buff, very beautiful in some women; but very little of this tint appears in the face. When a tinge of this warm buffy yellow and creamy yellow is seen mixed with warmer reds, as in the Gloire de Dijon rose, the effect is most beautiful and the expression most marked. But the expression in flowers of a pale dull, impure yellow, where there is an expression, is unpleasant. It is the yellow of unhealthy skins, of faces discolored by jaundice, dyspepsia, and other ailments. We commonly say of such flowers that they are "sickly" in color, and the association is with sick and decaying humanity. Gerarde,[11] in describing such hues in flowers, was fond of the word "overworn"; and it was a very good word, and, like the one now in use, is derived from the association.

5. THE ARTIFICIALITY OF GARDENS

It will be noted by those who are acquainted with many flowers that I have given the names of but few—it may be too few—as examples, and that these are nearly all of familiar wild flowers. My reason for not going to the garden is, that our cultivated blooms are not only artificially produced, and in some degree monstrosities, but they are seen in unnatural conditions, in crowds and masses, the various kinds too near

[11] John Gerarde (1545-1612). An English botanist.

together, and in most cases selected on account of their gorgeous coloring. The effect produced, however delightful it may be in some ways, is confusing to those simple natural feelings which flowers in a state of nature cause in us.

I confess that gardens in most cases affect me disagreeably; hence I avoid them, and think and know little about garden flowers. It is of course impossible not to go into gardens. The large garden is the greatly valued annex of the large house, and is as much or more to the mistress than the coverts to the master; and when I am asked to go into the garden to see and admire all that is there, I cannot say, "Madam, I hate gardens." On the contrary, I must weakly comply and pretend to be pleased. And when going the rounds of her paradise my eyes light by chance on a bed of tulips, or scarlet geraniums, or blue larkspurs, or detested calceolarias or cinerarias —a great patch of colored flame springing out of a square or round bed of grassless, brown, desolate earth—the effect is more than disagreeable: the mass of color glares at and takes possession of me, and spreads itself over and blots out a hundred delicate and prized images of things seen that existed in the mind.

6. ASSOCIATIONS WITH EARLY LIFE

But I am going too far, and perhaps making an enemy of a reader when I would much prefer to have him (or her) for a friend.

I have named few flowers, and those all the most familiar kinds, because it seemed to me that many examples would have had a confusing effect on readers who do not intimately know many species, or do not remember the exact color in each case, and are therefore unable to reproduce in their minds the exact *expression*—the feeling which every flower conveys. On

the other hand, the reader who knows and loves flowers, who has in his mind the distinct images of many scores, perhaps of two or three hundreds of species, can add to my examples many more from his own memory.

There is one objection to the explanation given here of the cause of the charm of certain flowers, which will instantly occur to some readers, and may as well be answered in advance. This view, or theory, must be wrong, a reader will perhaps say, because my own preference is for a yellow flower (the primrose or daffodil, let us say), which to me has a beauty and charm exceeding all other flowers.

The obvious explanation of such a preference would be that the particular flower preferred is intimately associated with recollections of a happy childhood, or of early life. The associations will have made it a flower among flowers, charged with a subtle magic, so that the mere sight or smell of it calls up beautiful visions before the mind's eye. Every person bred in a country place is affected in this way by certain natural objects and odors; and I recall the case of Cuvier,[12] who was always affected to tears by the sight of some common yellow flower, the name of which I have forgotten.

The way to test the theory is to take, or think of, two or three or half a dozen flowers that have no personal associations with one's own early life—that are not, like the primrose and daffodil in the foregoing instance, sacred flowers, unlike all others; some with and some without human coloring, and consider the feeling produced in each case on the mind. If any one will look at, say, a Gloire de Dijon rose (in some persons its mental image will serve as well as the object itself) and then at a perfect white chrysanthemum, or lily, or other beautiful white flower; then at a perfect yellow chrysan-

[12] Baron Georges Cuvier (1769-1832). A great French naturalist.

themum, or an allamanda, and at any exquisitely beautiful orchid, that has no human color in it, which he may be acquainted with, he will probably say: "I admire these chrysanthemums and other flowers more than the rose; they are most perfect in their beauty—I cannot imagine anything more beautiful; but though the rose is less beautiful and splendid, the admiration I have for it appears to differ somewhat in character—to be mixed with some new element which makes this flower actually more to me than the others."

That something different, and something more, is the human association which this flower has for us in virtue of its color; and the new element—the feeling it inspires, which has something of tenderness and affection in it—is one and the same with the feeling which we have for human beauty.

7. PERTINENT SUGGESTIONS

The foregoing has been given here with a few alterations, mainly verbal, as it appeared originally: something now remains to be added.

When writing about the wild flowers of West Cornwall in a work on *The Land's End* (1908), I returned to the subject of the charm of flowers due to their human coloring, and will repeat here much of what was there said.

Some of the readers of my flower chapter were not convinced that I had made out my case: it came as a surprise to them, and in some instances they cherished views of their own which they did not want to give up. Thus, two of my critics, writing independently, expressed their belief that flowers are precious to us and seem more beautiful than they are, because they are absolutely unrelated to our human life with its passions, sorrows, and tragedies—because, looking at flowers, we are taken into, or have glimpses of, another and brighter

world such as a disembodied spirit might find itself in. It was nothing more than a pretty fancy; but I had other more thoughtful critics, and during my correspondence with them I became convinced of a serious omission in my account of the blue flower, when I said that its expression was due to association with the blue eye in man. The strongest of my friendly adversaries informed me that any man can revel at will among his own personal feelings and associations; that these were a "kind of bloom on the intrinsic beauty of things"—a happy phrase! He then asks: "What does blue suggest to a sailor? Sometimes the sea, sometimes the sky, sometimes the Blue Peter;[13] but if you ask him what does blue paint suggest he would say *mourning,* that being the color of a ship's mourning. Dr. Sutton always called blue *no color,* because it was the color of death, the sign of the withdrawal of life."

This was interesting but fails as an argument since it was taken for granted in the chapter that blue in a flower or anything else, and in fact any color, possesses individual associations for every one of us, according to what we are, to the temper of our minds, to the conditions in which we exist, our vocation, our early life, and so on. Blue may suggest sea and sky and the Blue Peter to a sailor, and yet the blue flower have an expression due to its human association in him as in another.

But my critic dropped by chance into something better, when he went on to ask, "Why shouldn't the heaven's blue make us love flowers? It does in my case I know, and I can *feel* the different blues of skies and air and distance in flower blue."

Undoubtedly he was right; the blue sky, fair weather, the

[13] Blue Peter. A blue flag with a white square in the center, set as a signal that a vessel is about to sail.

open air, was a suggestion of the blue flower. It amazed me to think of the years I had spent under blue skies and of all I had felt about blue flowers, without stumbling upon this very simple fact. So simple, so near to the surface that you no sooner hear it than you imagine you have always known it! It was impossible to look at blue flowers and not be convinced of its truth, especially when the flowers were spread over considerable areas, as when I looked at wild hyacinths in the spring woods, or followed the interminable blue band of the vernal squill on the west Cornish coast, or saw large arid tracts of land in Suffolk blue with viper's bugloss.

Oddly enough just after the letter containing this criticism had reached me, another correspondent who was also among my opponents, sent me this fine passage from the old writer, Sir John Ferne,[14] on azure in blazoning: "Which blew colour representeth the Aire amongst the elements, that of all the rest is the greatest favourer of life, as the only nurse and maintainer of spirits in any living creature. The colour blew is commonly taken from the blew skye which appeareth so often as the tempests be overblowne, and notes prosperous successe and good fortune to the wearer in all his affayres."

In conclusion, after having adopted this new idea, my view is still that the human association is the principal factor in the expression of the blue flower, or at all events in a majority of flowers that bloom more or less sparingly and are usually seen as single blooms, not as mere splashes of color. Such are the pansy, violet, speedwell, hairbell, lungwort, blue geranium, etc. It may be that in all flowers of this kind, too, an element in the expression is due to the fair-weather associations with the color; but these associations must be very much

[14] Sir John Ferne (died about 1610). An English antiquary who wrote *Blazon of the Gentry* (1586).

stronger in the case of a blue flower always seen in masses and sheets of color as the wild hyacinth. Among dark-eyed races the fair-weather associations would alone give the blue flower its expression. I shouldn't wonder, if some explorer with a curious mind would try to find out what savages feel about flowers, that he would discover in them a special regard for the blue flower.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The Effect of Human Associations

1 How do resemblances to man affect our appreciation of nature?
2 What are some of the reasons why we admire flowers?
3 What does W. H. Hudson think an ideal way to write about nature?
4 To what does W. H. Hudson refer when he uses the word "expression"?

2 Associations with Blue

5 What may be some of the reasons for our admiration of color in various flowers?
6 Why do we admire some flowers more than others?
7 What is revealed by the popular names of certain flowers?
8 What do the names of flowers suggest concerning the story of race development?

3 Associations with Red

9 What is the secret of the charm of flowers?
10 Why do some flowers repel us?
11 Under what circumstances do flowers please us best?
12 Explain people's admiration of purple flowers.
13 What is your explanation of W. H. Hudson's preference for wild flowers?
14 Why do the bright red flowers win interest?

4 Associations with White and Yellow

15 What literary interests does W. H. Hudson show?
16 Why do many of the yellow flowers fail to make strong appeal?

17 What kinds of flowers are mentioned most by poets?
18 What knowledge of flowers does W. H. Hudson show? What is your theory concerning the manner in which he gained his information?
19 Why do some yellow flowers repel us?

5 The Artificiality of Gardens

20 Explain why flower gardens affect some people disagreeably.

6 Associations with Early Life

21 What facts explain admiration for certain flowers?
22 Explain why you prefer certain flowers.

7 Pertinent Suggestions

23 Present reasons for believing that W. H. Hudson's critics were, or were not, justified.
24 Explain the relationship between looking at the sky and admiring flowers.
25 How much do human associations have to do with our liking flowers?
26 What characteristics of W. H. Hudson does the essay suggest?
27 In what respects is W. H. Hudson a scientist? In what respects is he a literary artist?
28 Explain how W. H. Hudson combines science and literary art.
29 How does W. H. Hudson look upon nature?
30 Compare or contrast the work of W. H. Hudson with the work of some other observer of nature, such as John Burroughs.

BOOKS FOR FURTHER READING

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The Purple Land, W. H. Hudson, *Dutton,* 1916.
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Signs and Seasons, John Burroughs, *Houghton,* 1895.
Ways of Nature, John Burroughs, *Houghton,* 1905.
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In the Guinea Forest, James Rodway, *Scribner,* 1894.
Trees as Good Citizens, Charles L. Park, *American Tree,* 1923.
The Human Side of Trees, Royal Dixon and F. E. Fitch, *Stokes,* 1917.
The Human Side of Plants, Royal Dixon, *Stokes,* 1914.
Our National Forests, R. H. D. Boerker, *Macmillan,* 1918.
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A Treasury of Flower Stories, Inez McFee, *Crowell,* 1921.

THE INSECTS ARE WINNING

By

WILLIAM ATHERTON DU PUY

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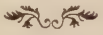

"There is, in fact, a war going on now—a thousand-year war, reported by the newspapers, financed out of tax money, as vital as the recent world conflict—of which the average citizen is not conscious. I refer to the war between man and the insects."

WILLIAM ATHERTON DU PUY.

WILLIAM ATHERTON DU PUY
(1876-)

Mr. William Atherton Du Puy's strong interest in nature study is indicated by the titles of some of his books: *Romances of Science—Our Insect Friends and Foes* (1924); *Our Bird Friends and Foes* (1925); and *Shadowtail the Squirrel* (1927).

Mr. Du Puy has led a life of varied interests, including the work of a newspaper reporter, manager of newspaper snydicates, editor, magazine contributor, and Government expert with the United States Bureau of Efficiency. He has travelled in many parts of the world.

Among his books, in addition to those named above, are the following: *Uncle Sam—Wonder Worker* (1913); *Uncle Sam's Modern Miracles* (1914); *Uncle Sam—Detective* (1915); *Uncle Sam—Fighter* (1918); *Is Corpulence a Crime?* (1919); *Humanism* (1921); *At Geneva* (1923); *Money* (1925); *Odd Jobs of Uncle Sam* (1926); *Lessons in Home Making* (1927).

THE INSECTS ARE WINNING

By William Atherton Du Puy

I. THE WAR BETWEEN MEN AND INSECTS

BACK in 1918 I heard a little girl, nine years old, ask her father this question: "What would the world be like without a war?"

It was a good deal of a shock to realize that here was a thinking person to whom war was normal. The great conflict had been going on ever since she could remember.

Now, if such a war should proceed without interruption through a generation, three generations, ten generations, thirty generations—would it become so commonplace a state, so generally accepted as a matter of course that all of us would become unconscious of it, would stop thinking of it as war? I maintain that it might, that it would, that this thing has actually come to pass. There is, in fact, a war going on now —a thousand-year war, reported by the newspapers, financed out of tax money, as vital as the recent world conflict—of which the average citizen is not conscious.

I refer to the war between man and the insects.

The issue is vital: no less than the life or death of the human race. If man wins he will remain the dominant species on this earth. If he loses he will be wiped out by this, his most ambitious racial enemy.

This enemy, this horde of insects that inhabits the earth, outnumbers all other kinds of animal life combined, has held its place for fifty million changing years, is beyond doubt

steadily increasing its power. It is finding its opportunity in the peculiar conditions developing in the world because of the interference of man himself.

Is there an insect age upon the ways just as there has been an age of reptiles, a glacial age, an age of man? Is the surge toward dominance of this seemingly suppressed class of the animal kingdom—the hexapoda, the six-legged animals—to last, or is it but a momentary flash in the pan? There is no question but that the present greatest menace to man's dominance is the increasing strength of the insects. If that strength continues to increase as it has for the past generation, a time will come when, his food supplies gone, man will disappear and the six-legged group will remain supreme.

The military intelligence divisions of the General Staffs of this war are composed of the students of insects, the Federal and State Bureaus of Entomology, the scientific institutions. They agree that the insects are gaining on man, that they threaten his very existence.

Here are evidences of the progress of the war between man and the insects:

When those of us who are now middle aged were boys, we picked our peaches and apples from trees in our own backyards. Our sons and daughters now buy them at the grocery store. They do this because the backyard orchards no longer exist: they cannot exist—the insects will not allow them to do so. They have won a battle in the thousand-year war. The result is a blow to man in the permanent curtailment of his food supply.

Here is another incident in the long war—one well known in itself but rarely considered in its relation to the age-long conflict of which it is a part. The boll weevil, as everybody knows, came out of the mountains of Mexico, pushed across

the Rio Grande, rolled on (fifty miles a year) blighting the cotton as it went, defying all the power of the strongest nation in the world to stop it until it had covered the cotton area. It cost America her cotton dominance of the world. It cut down man's supply of a useful material. Eventually, it seems, it must spread its blight around this world. Its invasions are a part of the thousand-year war.

Some readers well remember the coming to American orange groves, back in the nineties, of the cottony cushion scale. Out of Australia it came, a tiny thing which the eye could hardly see, stealing in on imported orange trees. In a few years all the orange trees of California were covered with it—individuals piled together in masses. Every individual in this army drilled itself a hole in the bark of the orange tree and began drinking sap. When enough of them got to drinking there was no sap left to nourish the tree and it died.

Man here used strategy. He sent emissaries to Australia, where the cottony cushion scale was native, to find out what kept it from killing the orange trees over there, to recruit mercenaries. They found that Australia had a peculiar variety of ladybird beetle which looked something like a potato bug and ate nothing but this scale. In Australia these kept the scale down, maintained the balance of nature. Give these ladybirds a happy home and plenty of food and they would multiply at a most appalling rate. One mother of to-day might, in five months, have seventy million descendants. So the scientists brought over some of these beetles, got them started in the orchards, set insect to eating insect, and in a year the scale was gone. Man had won a battle, had saved a resource—his orange crop.

About a decade ago a nurseryman of Riverton, New Jersey,

brought all the way from Japan some iris bulbs with earth around their roots. Though he did not know it there was a great menace lurking in these few spadefuls of dirt, a menace in the form of an insect enemy—the Japanese beetle. A few stowaway beetles thus introduced bred large families, and the next season they started out in all directions from their nursery and traveled five miles. They there dug themselves in for the winter and the next year traveled five more miles. They have widened their circle five miles every year since. Their march goes on, cannot be stopped, is as inevitable as the rising of the sun.

These beetles, while grubs, eat off the grass roots two inches below the ground, so that the covering of a lawn or golf course may be rolled up like a blanket. In a single square yard of sod fifteen hundred of them have been counted. They develop into beetles which fly away into the surrounding orchards and cornfields and devour them. The State of New Jersey, the State of Pennsylvania, and the Federal government have combined in attempts to throw a cordon around this marauder and stop him. The attempt has resulted in utter failure. The United States is suffering another successful insect invasion.

These are but isolated happenings in the thousand-year war. Witnessing one of them no more helps one to an understanding of the vast events which are slowly taking place than having seen the sinking of the *Lusitania*[1] would have explained Marshal Foch's[2] mission in the great crisis.

[1] *Lusitania.* On May 7, 1915, the Germans torpedoed the steamer *Lusitania,* causing the death of 114 United States citizens, and about 1,000 others.

[2] Ferdinand Foch (1851-). Marshal of France, the commander of French forces in the World War.

2. HISTORIC EVENTS IN THE GREAT WAR WITH INSECTS

To understand what is here going on one must get a grandstand seat so that he can look down on this world game as on the plays of the baseball diamond. He must concentrate decades into single plays, centuries into innings. So may man and the insect be seen as they fight it out.

In the days before Christ when Carthage,[3] sitting there on the north coast of Africa, was a city of magnificence, the grasshoppers used to be swept up from the desert by the winds, blown in myriads into the seas, and drowned. The waves would drift them onto the beach in barriers six feet deep and the stench of them would bring pestilences which cost hundreds of thousands of lives.

During the Middle Ages the flea brought the bubonic plague from its ancient nesting place among the black rats of the Himalayas and established it in Europe, where it persisted for centuries, killing half the people of a whole continent. The house fly (a purveyor of typhoid) and the mosquito (disseminator of malaria) have caused the death of more men and women since time began than all the wars between humans. The early sanguinary conflicts between man and insects were sporadic—were like medieval visits from marauders who came out of the mountains, or piratic fleets that fell upon unprotected towns and despoiled them. They were not like modern fighting, in which victory lies in exhausting the resources of the enemy. In its warfare with man the insect of to-day is applying a strategy the chief end of which is to leave its enemy without those supplies which will successfully sustain him.

There was a time not long ago when the balance of nature

[3] Carthage. The chief ancient city of northern Africa, and the great rival of Rome.

in this world was quite well established. Insects fed upon plants, birds upon insects, mammals upon birds. If the vegetation increased—insects had more abundant food, they increased in numbers and checked it. If the insects increased unduly—birds were well fed, bred bigger families, became numerous, ate up the surplus insects. If birds became overpowerful—beasts of prey were better nourished, increased in numbers, and called a halt in the expansion. If any of these elements became less abundant, then those which fed upon them were not fed so well, decreased in number, and gave their antagonists a better chance. So did nature tend to maintain a balance.

During the last thousand years a new element has appeared, has become steadily more important, has tended always more strongly to upset this balance of nature. This new element is man, who has but recently become the dominant living thing on this earth—the animal which has learned to adopt methods and practices beyond nature and through them to interfere with the normal balances of old. Here are some of the things that man has done which have disarranged the normal checks and counter-checks of nature.

Six thousand years ago in Egypt, when man first began to supplement himself by grouping about him other elements in nature, he found in the Numidian forest a brindled wild cat with black soles to its feet, which lent itself to domestication as has no other cat in the world, and took readily to the idea of living in man's household. Similar cats in the Numidian forests may be captured to-day and brought almost overnight to domestication. Wild cats of Europe and America are different: though tamed, they return to the wild at the first opportunity. This Numidian cat found its way into every Egyptian family. When traders first began to thread the Mediter-

ranean Sea they carried these pets to Athens, to Carthage, to Rome. There they multiplied and, with the passing generations, spread over all Europe, still maintaining almost in its purity this strain of the blackfooted beast from Egypt. Englishmen brought these cats to Massachusetts and Virginia. They increased in stupendous numbers, and to-day they blanket America. Millions of them live in American homes, but more millions have gone back to the wild and are scattered through its wastes. This Egyptian cat, once tamed, is to-day the most abundant representative of mammal wild life in America. Go into the woods anywhere after a snow and count the animal tracks, and more than half of them will be those of cats. These cats, if caught, will be found to have the black soles of the Egyptian.

Cats feed largely on birds. When man came to America there was a balance between bird life and that of the animals which preyed upon it. Man introduced a new element, the Egyptian cat, which has become dominant. These cats, preying on bird life, have upset the balance. There are fewer birds in America than there should be. Birds are one of nature's checks on insect life, and that check has been greatly weakened. Insects may breed to-day with less restraint than they did before. The cat is their effective ally.

3. CAUSES OF THE INCREASE OF CERTAIN INSECTS

Sir Francis Drake,[4] buccaneer of three hundred years ago, once took as a prize a Spanish ship loaded with spices from India. It is recorded that on that ship was a strange "black bugge" which the Spanish called *cucarache* which, strictly speaking, meant "wood louse." This *cucarache* became the

[4] Sir Francis Drake (1540-1596). A great English sea-captain and explorer.

modern cockroach. It was a native of India, never until that time seen in Europe. These cockroaches, however, were sturdy fellows, given to living in dark and narrow places, and therefore happy in the holds of ships that plied the seas. Thus these argosies of commerce have served as a means of broadcasting the cockroach, and it is found in abundance wherever man dwells. His homes have provided suitable breeding and dwelling places for these children of the warm countries. New species, one in America and one in Australia, were found and distributed. So have world-girdling multitudes of them appeared where before there were none at all or but local tribes. This increase in the range and numbers of the cockroach is typical of the man-influence in the insect world.

In 1889 a scientist in Medford, Massachusetts, was conducting experiments for the improvement of the breed of silkworms. Moths are the mothers of these spinners and he was attempting to develop a hardier moth, one with caterpillars that would browse on scrub oak or sassafras. To this end he brought over from Europe a specimen known as the gipsy moth because of its bronzed complexion. He caged this dusky adventurer with timid little mothers of silkworms, hoping they would mate. Along came a boisterous wind and blew over the coop. The gipsy moths flew away and merged themselves into the Massachusetts landscape.

This small incident launched a new campaign in the thousand-year war. The gipsy moths, which are quite harmless in their native Europe, multiplied in America to a prodigious extent. In a decade their caterpillars were so numerous that they were eating the foliage from a distressing proportion of the trees in Massachusetts. Not only this but they were gradually extending their range over into Connecticut, up into New Hampshire, on into Maine. They were creating devasta-

tion—they were menacing the trees of one entire corner of the United States and threatening always the conquest of new areas. Again were individual states aroused to action. Again did the Federal government fling its resources into the field. Again was the scientific world called upon to furnish strategists in a great campaign. For thirty years the fight has gone on—the advantage now on the one side and now on the other, with the outcome as yet undetermined.

Here again, however, it has been the intervention of man which has given the insects an opportunity to harm him, to attack in a new way.

The manner in which this thousand-year war may bring about unexpected situations is most surprising. Here, for instance, is an incident of felicitous comity between two friendly nations which, by the intrusion of an insect, has been turned into costly tragedy.

Theodore Roosevelt, while President, sent his Secretary of War[5] on a world-girdling trip, the result of which was the establishment of certain international friendships. In the course of this trip Mrs. Taft was presented to the Empress of Japan. Later, when Mr. Taft became President, that sovereign, seeking to give evidence of an enduring friendship, sent to Mrs. Taft a group of flowering cherry trees, symbols of beauty from the Far East. Those cherry trees were planted along the tidal basin in Washington and their beauty in the springtime has become a matter of national renown and pride. Some years after the planting of these trees, however, an entomologist found in a peach tree near Washington a queer little moth, the like of which he had never seen before. Identification of the stranger was a matter of months, but in the end

[5] William Howard Taft (1857-). Secretary of War, 1904-1908; President of the United States, 1909-1913.

it was shown that he was a member of a moth race resident in the Orient. He was a peach moth. Coming in on these cherry trees, he has started another widening circle which as it grows blights all the peaches. Fluffy and fluttering in its frailty, this moth has thrown down the gauntlet to America, has challenged her to fight for a great prize, a prize no other than her peach crop which spreads from ocean to ocean. It started a conflict that will continue for generations, and its result may be the loss to man of another important food resource.

These recurring battles between man and insects, as I have said, mostly find their origin in some act of man himself. The boll weevil, for example, which had existed for a million years in the hills of Mexico, was an insect of no importance, with a localized home, until an act of man gave it an unusual opportunity. Man took the cotton tree of the tropics—a plant which in its native state grows on, year after year, as does an apple tree. He brought it to the temperate zone, nursed it, converted it into an annual which died every year when the frost came, adapted it to cultivation in the fields, made it the basis of a crop of world importance. Many decades passed and eventually some few weevils of these Mexican mountain tribes were brought by man down to the Rio Grande and carried in cotton seed over into Texas, where cotton fields spread out unendingly. The check upon the spread of the boll weevil in its native home had been the limited supply of cotton trees which offered it a breeding place. Here were prepared for it—through the agency of man—limitless pasture lands, inexhaustible food supplies, opportunity to increase beyond the dreams of fancy. The one check to its increase had been removed and the boll weevil—obeying its innate law—swept

on irresistibly, defeated the forces of the United States in every battle until it had blanketed the South.

The backyard orchard has disappeared because of the coming—again from the Orient, as in the case of the scale that attacked the orange groves, and again through the agency of man—of a tiny insect which, breeding in millions in your apple tree, has come to be known as the San José scale. San José scale has spread through the nation. It has spread in the face of all the resistance that science has been able to offer. The battle which has now lasted three decades has come to a deadlock. The invader admits that the orchardist may hold it in check by one device, and one only: if he sprays his trees with poison at the right moment, four or five times a year, so that San José scale may not feed upon them and his fruit may ripen. If he does not do this scientifically, periodically, the scale will thrive and the fruit crop will be spoiled. Practically, it works out that the fruit grower with great orchards, scientifically handled, may successfully fight the San José scale; but the individual with a small plot will not take the pains, cannot afford to take the pains necessary to save his fruit.

The gipsy moth invasion, like that of the boll weevil, did not yield quickly to treatment as did the cottony cushion scale. Every effort was made through the decades of fighting to find parasites that would check it, enemies that would prey upon it and devour it. Some such have been found. There is *Calosoma,* the tree-climbing beetle from Europe which feeds on caterpillars; and *Anastatus,* the tiny wasp that lays its eggs in the gipsy-moth eggs; another wasp, a Japanese, that lays its eggs inside the caterpillar itself where it eats out its vitals; and a tricky fly which lays its eggs on the leaves, where they are swallowed by the caterpillar and the young ones develop and bore from within. All of these have been introduced by

the strategists and it looks as if they had at last got the better of the gipsy moth. The most effective enemies of insects have been found to be other insects.

4. PROMISES FOR THE FUTURE

What is to be the issue in the fight with the Japanese beetle and the peach moth is yet in the lap of the gods. What are to be the new issues in the long war only the future can tell. In any waste corner of the world insect menaces like the boll weevil or the Japanese beetle, or worse, may be lying dormant to be given their opportunity by some act of man which interferes with nature's adjustments.

An understanding of these problems of the insect menace is largely due to findings of the present generation. Before it there were a few outstanding entomologists, but their numbers were small and their interest largely theoretical. The grasshopper invasion of the western wheat fields in the days of our fathers gave a tremendous impetus to applied entomology. Scientific men began to study the grasshopper, whence it came, how it might be fought. Individuals in the universities here and there began to specialize on a study of insects and their relations to human welfare. A generation ago so simple a thing as the fact that house flies bred in manure piles was unknown. A generation ago lumbermen did not know that a "red top" in the forest was a tree with its throat cut; that it was being girdled by a beetle beneath its bark which, if not fought, might destroy the whole forest. A generation ago there were few people who knew that the insects were man's most ambitious rival for world supremacy, and that the logic of the situation was that in the end they would probably wipe him out.

The foremost world agency in the development of applied entomology has been the United States Department of Agri-

culture. Its Bureau of Entomology, with some four hundred scientific men employed—the largest agency of its kind in existence—has steadily led the world in this field. Dr. L. O. Howard,[6] its chief, has spent forty-eight years in its development and has been an outstanding figure in organizing governmental opposition to insect attack.

These scientists are the staff officers, the intelligence corps of the thousand-year war. They are able to get perspective on its progress. They set the occasional victory which man has gained over against his more frequent defeats. They balance the ledger and find that man has lost many more fights than he has won. They measure the increase in the strength of the enemy through a generation or a century and find that it is appalling. They visualize the result if developments should continue as they have been for a hundred or a thousand years. The prospect for man, they hold, is not bright.

Strange antagonists are these two—*genus homo* and the insect—the graybeard and the youth of the animal kingdom. In coal beds that were laid down five million years ago are found the remains of cockroaches very much like those that forage in pantries of to-day—wise enough to detect, with a single touch of an antenna, the presence of poison man has stirred into their favorite food. They have been so fit to survive that they have found no need of change. Beside them man is a mere stripling, an experimental design come into the world but yesterday—some thirty-five thousand years ago—a design which is constantly being changed, whose success or failure is yet to be demonstrated.

How contemptuous of the upstart must be this representative of an established order, of a family that has held its place

[6] Leland O. Howard (1857-). Chief of the Bureau of Entomology since 1894.

through the ages! How the cockroach must scratch his wise old head and chuckle as he remembers that time when huge reptiles strutted the marshes and ruled the world; when marsupials, stupid grandfathers of the opossum, held sway; when mastodons but yesterday had their fling! And now this youngster! Wait and see!

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The War Between Men and Insects

1 Explain why the introduction of the article is effective.
2 How does Mr. Du Puy show the importance of his subject?
3 Show how Mr. Du Puy carries out the figure of speech on which he founds the article.
4 By what means does Mr. Du Puy lead us to believe his statement that the insects are winning?
5 How does man employ insects to fight insects?
6 What shows the importance of protecting the United States from foreign insect pests?

2 Historic Events in the Great War with Insects

7 What great losses have insects brought upon the world at various times?
8 What great contrast exists between the results of war, and the work of the fly and the mosquito?
9 Explain the term, "The balance of nature."
10 What was the origin of the house-cat?
11 How has the cat affected civilization?

3 Causes of the Increase of Certain Insects

12 Tell the story of the cockroach.
13 Tell the story of the gypsy moth.
14 Tell the story of the peach moth.
15 Why did the boll weevil become a menace?
16 What losses have been caused by the San José scale?
17 What is one of the best ways to fight insect pests?

4 Promises for the Future

18 What led to the scientific study of insect life?
19 Explain the importance of entomology.
20 What does the United States government do to aid in the war against insects?
21 How old are the insects as compared with man?
22 Explain what the article gains because of its use of comparison.

BOOKS FOR FURTHER READING

Romance of Science—Our Insect Friends and Foes, William Atherton Du Puy, *Winston,* 1925.
Our Bird Friends and Foes, William Atherton Du Puy, *Winston,* 1925.
Injurious Insects, W. C. O'Kane, *Macmillan,* 1912.
Insect Pests of Farm, Garden and Orchard, E. D. Sanderson, *John Wiley,* 1921.
Fighting Foes Too Small to See, Joseph McFarland, *Davis,* 1924.
Ants, Their Structure, Development and Behavior, William Morton Wheeler, *Lemcke,* 1910.
The Life of the Bee, Maurice Maeterlinck, *Dodd,* 1902.
Social Life Among the Insects, William Morton Wheeler, *Harcourt,* 1923
Insect Stories, Vernon Kellogg, *Appleton,* 1923.
Busy, the Life of an Ant, Walter F. McCaleb, *Harper,* 1919.
Happy, the Life of a Bee, Walter F. McCaleb, *Harper,* 1917.

SECRETS OF THE OCEAN

By

WILLIAM BEEBE

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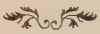

"One may spend days of leisure or delightful study among the abundant and ever changing variety of wonderful living creatures."

WILLIAM BEEBE.

WILLIAM BEEBE
(1877-)

William Beebe's delightful books, that so well unite science and popular interest, make him one of the best known of modern scientific writers.

Mr. Beebe is Curator of Ornithology for the New York Zoölogical Society, and the active Director of the Department of Scientific Research; Fellow of the New York Academy of Sciences; member of the American Association for the Advancement of Science, and member of many other scientific bodies. His various scientific expeditions to Nova Scotia, Mexico, Venezuela, British Guiana, the Himalayas, Borneo, China, Japan, the Galapagos Islands, and the Sargasso Sea, attracted wide attention.

Everyone who enjoys the essay that follows should read all of *The Log of the Sun,* from which it is taken.

Among Mr. Beebe's books are the following: *Two Bird Lovers in Mexico* (1905); *The Bird* (1906); *The Log of the Sun* (1906); *Our Search for a Wilderness* (1910); *Tropical Wild Life* (1917); *Monographs of the Pheasants* (1918); *Jungle Peace* (1918); *The Edge of the Jungle* (1921); *Galapagos: World's End* (1923); *Jungle Days* (1925); *Pheasants—Their Lives and Homes* (1926); *Pheasant Jungles* (1927).

SECRETS OF THE OCEAN

By William Beebe

I. INTEREST OF THE SEASHORE

WE ARE often held spellbound by the majesty of mountains, and indeed a lofty peak forever capped with snow, or pouring forth smoke and ashes, is impressive beyond all terrestrial things. But the ocean yields to nothing in its grandeur, in its age, in its ceaseless movement, and the question remains forever unanswered, "Who shall sound the mysteries of the sea?" Before the most ancient of mountains rose from the heart of the earth, the waves of the sea rolled as now, and though the edges of the continents shrink and expand, bend into bays or stretch out into capes, always through all the ages the sea follows and laps with ripples or booms with breakers unceasingly upon the shore.

Whether considered from the standpoint of the scientist, the mere curiosity of the tourist, or the keen delight of the enthusiastic lover of Nature, the shore of the sea—its sands and waters, its ever-changing skies and moods—is one of the most interesting spots in the world. The very bottom of the deep bays near shore—dark and eternally silent, prisoned under the restless waste of waters—is thickly carpeted with strange and many-colored forms of animal and vegetable life. But the beaches and tide-pools over which the moon-urged tides hold sway in their ceaseless rise and fall, teem with marvels of Nature's handiwork, and every day are restocked and replanted

with new living objects, both arctic and tropical offerings of each heaving tidal pulse.

Here on the northeastern shores of our continent one may spend days of leisure or delightful study among the abundant and ever changing variety of wonderful living creatures. It is not unlikely that the enjoyment and absolute novelty of this new world may enable one to look on these as some of the most pleasant days of life. I write from the edge of the restless waters of Fundy,[1] but any rock-strewn shore will duplicate the marvels.

2. THE SEASHORE AT HIGH TIDE

At high tide the surface of the Bay is unbroken by rock or shoal, and stretches glittering in the sunlight from the beach at one's feet to where the New Brunswick shore is just visible, appearing like a low bluish cloud on the horizon. At times the opposite shore is apparently brought nearer and made more distinct by a mirage, which inverts it, together with any ships which are in sight. A brig may be seen sailing along keel upward, in the most matter-of-fact way. The surface may anon be torn by those fearful squalls for which Fundy is noted, or, calm as a mirror, reflect the blue sky with an added greenish tinge, troubled only by the gentle alighting of a gull, the splash of a kingfisher or occasional osprey, as these dive for their prey, or the ruffling which shows where a school of mackerel is passing. This latter sign always sends the little sailing dories hurrying out, where they beat back and forth, like shuttles traveling across a loom, and at each turn a silvery struggling form is dragged into the boat.

A little distance along the shore the sandy beach ends and

[1] Fundy. Mr. Beebe wrote on the shores of the Bay of Fundy, the great inlet between New Brunswick and Nova Scotia.

is replaced by huge bare boulders, scattered and piled in the utmost confusion. Back of these are scraggly spruces, with branches which have been so long blown landwards that they have bent and grown altogether on that side,—permanent weather-vanes of Fundy's storms. The very soil in which they began life was blown away, and their gnarled weather-worn roots hug the rocks, clutching every crevice as a drowning man would grasp an oar. On the side away from the bay two or three long, thick roots stretch far from each tree to the nearest earth-filled gully, sucking what scanty nourishment they can, for strength to withstand the winter's gales yet another year or decade. Beach-pea and sweet marsh lavender tint the sand, and stunted fringed orchids gleam in the coarse grass farther inland. High up among the rocks, where there is scarcely a handful of soil, delicate harebells sway and defy the blasts, enduring because of their very pliancy and weakness.

If we watch awhile we will see a line of blackish seaweed and wet sand appearing along the edge of the water, showing that the tide has turned and begun to recede. In an hour it has ebbed a considerable distance, and if we clamber down over the great weather-worn rocks the hardy advance guard of that wonderful world of life under the water is seen. Barnacles whiten the top of every rock which is reached by the tide, although the water may cover them only a short time each day. But they flourish here in myriads, and the shorter the chance they have at the salt water the more frantically their little feathery feet clutch at the tiny food particles which float around them. These thousands of tiny turreted castles are built so closely together that many are pressed out of shape, paralleling in shape as in substance the inorganic crystals of the mineral kingdom. The valved doors are continually open-

ing and partly closing, and if we listen quietly we can hear a perpetual shuss! shuss! Is it the creaking of the tiny hinges? As the last receding wave splashes them, they shut their folding doors over a drop or two and remain tightly closed, while perhaps ten hours of sunlight bake them, or they glisten in the moonlight for the same length of time, ready at the first touch of the returning water to open wide and welcome it.

The thought of their life history brings to mind how sadly they retrogress as they grow, hatching as minute free-swimming creatures like tiny lobsters, and gradually changing to this plant-like life, *sans*[2] eyes, *sans* head, *sans* most everything except a stomach and a few pairs of feathery feet to kick food into it. A few pitiful traces of nerves are left them. What if there were enough ganglia to enable them to dream of their past higher life, in the long intervals of patient waiting!

A little lower down we come to the zone of mussels,—hanging in clusters like some strange sea-fruit. Each is attached by strands of thin silky cables, so tough that they often defy our utmost efforts to tear a specimen away. How secure these creatures seem, how safe from all harm, and yet they have enemies which make havoc among them. At high tide fishes come and crunch them, shells and all, and multitudes of carnivorous snails are waiting to set their file-like tongues at work, which mercilessly drill through the lime shells, bringing death in a more subtle but no less certain form. Storms may tear away the support of these poor mollusks, and the waves dash them far out of the reach of the tides, while at low water, crows and gulls use all their ingenuity to get at their toothsome flesh.

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[2] Sans. The French word for "without," used here in allusion to Shakespeare's line: "Sans teeth, sans eyes, sans taste, sans everything," *As You Like It:* II, 7, 166.

3. THE SEASHORE AT LOW TIDE

There are no ant-hills in the sea, but when we turn over a large stone and see scores upon scores of small black shrimps scurrying around, the resemblance to those insects is striking. These little creatures quickly hitch away on their sides, getting out of sight in a remarkably short time.

The tide is going down rapidly, and following it step by step novel sights meet the eye at every turn, and we begin to realize that in this narrow strip, claimed alternately by sea and land, which would be represented on a map by the finest of hair-lines, there exists a complete world of animated life, comparing in variety and numbers with the life in that thinner medium, air. We climb over enormous boulders, so different in appearance that they would never be thought to consist of the same material as those higher up on the shore. These are masses of wave-worn rock, twenty or thirty feet across, piled in every imaginable position, and completely covered with a thick padding of seaweed. Their drapery of algæ[3] hangs in festoons, and if we draw aside these submarine curtains, scenes from a veritable fairyland are disclosed. Deep pools of water, clear as crystal and icy cold, contain creatures both hideous and beautiful, somber and iridescent, formless and of exquisite shape.

4. SEA-ANEMONES

The sea-anemones first attract attention, showing as splashes of scarlet and salmon among the olive-green seaweed, or in hundreds covering the entire bottom of a pool with a delicately hued mist of waving tentacles. As the water leaves these exposed on the walls of the caves, they lose their plump appear-

[3] Algæ. Various forms of seaweed.

ance and, drawing in their wreath of tentacles, hang limp and shrivelled, resembling pieces of water-soaked meat as much as anything. Submerged in the icy water they are veritable animal-flowers. Their beauty is indeed well guarded, hidden by the overhanging seaweed in these caves twenty-five feet or more below high-water mark.

Here in these beautiful caverns we may make aquariums, and transplant as many animal-flowers as we wish. Wherever we place them their fleshy, snail-like foot spreads out, takes tight hold, and the creature lives content, patiently waiting for the Providence of the sea to send food to its many wide-spread fingers.

Carpeted with pink algæ and dainty sponges, draped with sea-lettuce like green tissue paper, decorated with strange coralines, these natural aquariums far surpass any of artificial make. Although the tide drives us from them sooner or later, we may return with the sure prospect of finding them refreshed and perhaps replenished with many new forms. For often some of the deep-water creatures are held prisoners in the lower tide-pools, as the water settles, somewhat as when the glaciers receded northward after the Ice Age there were left on isolated mountain peaks traces of the boreal fauna and flora.

If we are interested enough to watch our anemones we will find much entertainment. Let us return to our shrimp colonies and bring a handful to our pool. Drop one in the center of an anemone and see how quickly it contracts. The tentacles bend over it exactly as the sticky hairs of the sun-dew plant close over a fly. The shrimp struggles for a moment and is then drawn downward out of sight. The birth of an anemone is well worth patient watching, and this may take place in several different ways. We may see a large individual with a number of tiny bunches on the sides of the body, and if we

keep this one in a tumbler, before long these protuberances will be seen to develop a few tentacles and at last break off as perfect miniature anemones. Or again, an anemone may draw in its tentacles without apparent cause, and after a few minutes expand more widely than ever. Suddenly a movement of the mouth is seen, and it opens, and one, two, or even a half-dozen tiny anemones shoot forth. They turn and roll in the little spurt of water and gradually settle to the rock alongside of the mother. In a short time they turn right side up, expand their absurd little heads, and begin life for themselves. These animal "buds" may be of all sizes; some minute ones will be much less developed and look very unlike the parent. These are able to swim about for a while, and myriads of them may be born in an hour. Others, as we have seen, have tentacles and settle down at once.

5. FISH AND JELLY-FISH

Fishes, little and big, are abundant in the pools, darting here and there among the leathery fronds of "devils' aprons," cavernous-mouthed angler fish, roly-poly young lump-suckers, lithe butter-fish and many others.

Moving slowly through the pools are many beautiful creatures, some so evanescent that they are only discoverable by the faint shadows which they cast on the bottom, others suggest animated spheres of prismatic sunlight. These latter are tiny jelly-fish, circular hyaline[4] masses of jelly with eight longitudinal bands, composed of many comb-like plates, along which iridescent waves of light continually play. The graceful appearance of these exquisite creatures is increased by two long, fringed tentacles streaming behind, drifting at full length or contracting into numerous coils. The fringe on these

[4] Hyaline. Transparent.

BUFFALO, N. Y.

streamers is a series of living hairs—an aquatic cobweb, each active with life, and doing its share in ensnaring minute atoms of food for its owner. When dozens of these *ctenophores* (or comb-bearers) as they are called, glide slowly to and fro through a pool, the sight is not soon forgotten. To try to photograph them is like attempting to portray the substance of a sunbeam, but patience works wonders, and even a slightly magnified image of a living jelly is secured, which shows very distinctly all the details of its wonderfully simple structure; the pouch, suspended in the center of the sphere, which does duty as a stomach; the sheaths into which the long tentacles may be so magically packed, and the tiny organ at the top of this living ball of spun glass, serving, with its minute weights and springs, as compass, rudder, and pilot to this little creature, which does not fear to pit its muscles of jelly against the rush and might of breaking waves.

Even the individual comb-plates or rows of oars are plainly seen, although, owing to their rapid motion, they appear to the naked eye as a single band of scintillating light. This and other magnified photographs were obtained by fastening the lens of a discarded bicycle lantern in a cone of paper blackened on the inside with shoe-blacking. With this crude apparatus placed in front of the lens of the camera, the evanescent beauties of these most delicate creatures were preserved.

Other equally beautiful forms of jelly-fish are balloon-shaped. These are *Beröe,*[5] fitly named after the daughter of the old god Oceanus. They, like others of their family, pulsate through the water, sweeping gracefully along, borne on currents of their own making.

[5] Beröe. According to Greek legend a sea symph, daughter of Oceanus, god of the earth-surrounding waters.

6. STARFISH AND SEA-URCHINS

Passing to other inhabitants of the pools, we find starfish and sea-urchins everywhere abundant. Hunched-up groups of the former show where they are dining in their unique way on unfortunate sea-snails or anemones, protruding their whole stomach and thus engulfing their victim. The urchins strain and stretch with their innumerable sucker-feet, feeling for something to grasp, and in this laborious way pull themselves along. The mouth, with the five so-called teeth, is a conspicuous feature, visible at the center of the urchin and surrounded by the greenish spines. Some of the starfish are covered with long spines, others are nearly smooth. The colors are wonderfully varied,—red, purple, orange, yellow, etc.

The stages through which these prickly skinned animals pass, before they reach the adult state, are wonderfully curious, and only when they are seen under the microscope can they be fully appreciated. A bolting-cloth net drawn through some of the pools will yield thousands in many stages, and we can take eggs of the common starfish and watch their growth in tumblers of water. At first the egg seems nothing but a tiny round globule of jelly, but soon a dent or depression appears on one side, which becomes deeper and deeper until it extends to the center of the egg-mass. It is as if we should take a round ball of putty and gradually press our finger into it. This pressed-in sac is a kind of primitive stomach and the entrance is used as a mouth. After this follows a marvellous succession of changes, form giving place to form, differing more in appearance and structure from the five-armed starfish than a caterpillar differs from a butterfly.

For example, when about eight days old, another mouth has formed and two series of delicate cilia or swimming hairs

wind around the creature, by means of which it glides slowly through the water. The photographs of a starfish of this age show the stomach with its contents, a dark rounded mass near the lower portion of the organism. The vibrating bands which outline the tiny animal are also visible. The delicacy of structure and difficulty of preserving these young starfish alive make these pictures of particular value, especially as they were taken of the living forms swimming in their natural element. Each day and almost each hour adds to the complexity of the little animal, lung tentacles grow out and many other larval stages are passed through before the starfish shape is discernible within this curious "nurse" or living, changing egg. Then the entire mass, so elaborately evolved through so long a time, is absorbed and the little baby star sinks to the bottom to start on its new life, crawling around and over whatever happens in its path and feeding to repletion on succulent oysters. It can laugh at the rage of the oysterman, who angrily tears it in pieces, for "time heals all wounds" literally in the case of these creatures, and even if the five arms are torn apart, five starfish, small of arm but with healthy stomachs, will soon be foraging on the oyster bed.

7. SEA-WORMS, SHRIMPS, AND PRAWNS

But to return to our tide-pools. In the skimming net with the young starfish many other creatures are found, some so delicate and fragile that they disintegrate before microscope and camera can be placed in position. I lie at full length on a soft couch of seaweed with my face close to a tiny pool no larger than my hand. A few armadillo shells and limpets crawl on the bottom, but a frequent troubling of the water baffles me. I make sure my breath has nothing to do with it, but still it continues. At last a beam of sunshine lights up the

pool, and as if a film had rolled from my eyes I see the cause of the disturbance. A sea-worm—or a ghost of one—is swimming about. Its large, brilliant eyes, long tentacles, and innumerable waving appendages are now as distinct as before they had been invisible. A trifling change in my position and all vanishes as if by magic. There seems not an organ, not a single part of the creature, which is not as transparent as the water itself. The fine streamers into which the paddles and gills are divided are too delicate to have existence in any but a water creature, and the least attempt to lift the animal from its element would only tear and dismember it, so I leave it in the pool to await the return of the tide.

Shrimps and prawns of many shapes and colors inhabit every pool. One small species, abundant on the algæ, combines the color changes of a chameleon with the form and manner of travel of a measuring-worm, looping along the fronds of seaweed or swimming with the same motion. Another variety of shrimp resembles the common wood-louse found under pieces of bark, but is most beautifully iridescent, glowing like an opal at the bottom of the pool. The curious little sea-spiders keep me guessing for a long time where their internal organs can be, as they consist of legs with merely enough body to connect these firmly together. The fact that the thread-like stomach and other organs send a branch into each of the eight legs explains the mystery and shows how far economy of space may go. Their skeleton-forms, having the appearance of eight straggling filaments of seaweed, are thus, doubtless, a great protection to these creatures from their many enemies. Other hobgoblin forms with huge probosces crawl slowly over the floors of the anemone caves, or crouch as the shadow of my hand or net falls upon them.

The larger gorgeously colored and graceful sea-worms con-

tribute not a small share to the beauty of Fundy tide-pools, swimming in iridescent waves through the water or waving their Medusa-head [6] of crimson tentacles at the bottom among the sea-lettuce. These worms form tubes of mud for themselves, and the rows of hooks on each side of the body enable them to climb up and down in their dismal homes.

8. HYDROIDS

Much of the seaweed from deeper bottoms seems to be covered with a dense fur, which under a hand lens resolves into beautiful hydroids,—near relatives of the anemones and corals. Scientists have happily given these most euphonious names—*Campanularia,*[7] *Obelia,*[8] and *Plumularia.*[9] Among the branches of certain of these, numbers of round discs or spheres are visible. These are young medusæ or jelly-fish, which grow like bunches of currants, and later will break off and swim around at pleasure in the water. Occasionally one is fortunate enough to discover these small jellies in a pool where they can be photographed as they pulsate back and forth. When these attain their full size they lay eggs which sink to the bottom and grow up into the plant-like hydroids. So each generation of these interesting creatures is entirely unlike that which immediately precedes or follows it. In other words, a hydroid is exactly like its grandmother and granddaughter, but as different from its parents and children in appearance as a plant is from an animal. Even in a fairy-story book this would be wonderful, but here it is taking place under our very eyes, as

[6] Medusa-head. A Greek legend says that the hair of Medusa, one of the Gorgons, was changed into serpents.

[7] Campanularia. From the Latin, *campanula,* a bell.

[8] Obelia. From the Greek, *obelos,* a pointed rod.

[9] Plumularia. From the Latin, *pluma,* a feather.

are scores of other transformations and "miracles in miniature" in this marvellous underworld.

9. UNDER THE SURFACE

Now let us deliberately pass by all the attractions of the middle zone of tide-pools and on as far as the lowest level of the water will admit. We are far out from the shore and many feet below the level of the barnacle-covered boulders over which we first clambered. Now we may indeed be prepared for strange sights, for we are on the very border-land of the vast unknown. The abyss in front of us is like planetary space, unknown to the feet of man. While we know the latter by scant glimpses through our telescopes, the former has only been scratched by the hauls of the dredge, the mark of whose iron shoe is like the tiny track of a snail on the leaf mould of a vast forest.

The first plunge beneath the icy waters of Fundy is likely to remain long in one's memory, and one's first dive of short duration, but the glimpse which is had and the hastily snatched handfuls of specimens of the beauties which no tide ever uncovers, is potent to make one forget his shivering and again and again seek to penetrate as far as a good-sized stone and a lungful of air will carry him. Strange sensations are experienced in these aquatic scrambles. It takes a long time to get used to pulling oneself *downward,* or propping your knees against the *under* crevices of rocks. To all intents and purposes, the law of gravitation is partly suspended, and when stone and wooden wedge accidentally slip from one's hand and disappear in *opposite* directions, it is confusing, to say the least.

When working in one spot for some time the fishes seem to become used to one, and approach quite closely. Slick-looking pollock, bloated lump-fish, and occasionally a sombre dog-

fish rolls by, giving one a start, as the memory of pictures of battles between divers and sharks of tropical waters comes to mind. One's mental impressions made thus are somewhat disconnected. With the blood buzzing in the ears, it is only possible to snatch general glimpses and superficial details. Then at the surface, notes can be made, and specimens which have been overlooked, felt for during the next trip beneath the surface. Fronds of laminaria [10] yards in length, like sheets of rubber, offer convenient holds, and at their roots many curious creatures make their home. Serpent starfish, agile as insects and very brittle, are abundant, and new forms of worms, like great slugs,—their backs covered with gills in the form of tufted branches.

In these outer, eternally submerged regions are starfish of still other shapes, some with a dozen or more arms. I took one with thirteen rays and placed it temporarily in a pool aquarium with some large anemones. On returning in an hour or two I found the starfish trying to make a meal of the largest anemone. Hundreds of dart-covered strings had been pushed out by the latter in defence, but they seemed to cause the starfish no inconvenience whatever.

In my submarine glimpses I saw spaces free from seaweed on which hundreds of tall polyps were growing, some singly, others in small tufts. The solitary individuals rise three or four inches by a nearly straight stalk, surmounted by a many-tentacled head. This droops gracefully to one side and the general effect is that of a bed of rose-colored flowers. From the heads hang grape-like masses, which on examination in a tumbler are seen to be immature medusæ. Each of these develop to the point where the four radiating canals are discernible and

[10] Laminaria. Large seaweeds.

then their growth comes to a standstill, and they never attain the freedom for which their structure fits them.

When the wind blew inshore, I would often find the water fairly alive with large sun-jellies or *Aurelia,*—their Latin name. Their great milky-white bodies would come heaving along and bump against me, giving a very "crawly" sensation. The circle of short tentacles and the four horseshoe-shaped ovaries distinguish this jelly-fish from all others. When I had gone down as far as I dared, I would sometimes catch glimpses of these strange beings far below me, passing and repassing in the silence and icy coldness of the watery depths. These large medusæ are often very abundant after a favorable wind has blown for a few days, and I have rowed through masses of them so thick that it seemed like rowing through thick jelly, two or three feet deep. In an area the length of the boat and about a yard wide, I have counted over one hundred and fifty *Aurelias* on the surface alone.

When one of these "sun-fish," as the fishermen call them, is lifted from the water, the clay-colored eggs may be seen to stream from it in myriads. In many jellies, small bodies the size of a pea are visible in the interior of the mass, and when extracted they prove to be a species of small shrimp. These are well adapted for their quasi-parasitic life, in color being throughout of the same milky semi-opaqueness as their host, but one very curious thing about them is, that when taken out and placed in some water in a vial or tumbler they begin to turn darker almost immediately, and in five minutes all will be of various shades, from red to a dark brown.

I had no fear of *Aurelia,* but when another free-swimming species of jelly-fish, *Cyanea,* or the blue-jelly, appeared, I swam ashore with all speed. This great jelly is usually more of a reddish liver-color than a purple, and is much to be dreaded

Its tentacles are of enormous length. I have seen specimens which measured two feet across the disc, with streamers fully forty feet long, and one has been recorded seven feet across and no less than one hundred and twelve feet to the tip of the cruel tentatcles! These trail behind in eight bunches and form a living, tangled labyrinth as deadly as the hair of the fabled Medusa—whose name indeed has been so appropriately applied to this division of animals. The touch of each tentacle to the skin is like a lash of nettle, and there would be little hope for a diver whose path crossed such a fiery tangle. The untold myriads of little darts which are shot out secrete a poison which is terribly irritating.

On the crevice bottoms a sight now and then meets my eyes which brings the "devil-fish" of Victor Hugo's [11] romance vividly to mind,—a misshapen squid making its way snakily over the shells and seaweed. Its large eyes gaze fixedly around and the arms reach alternately forward, the sucking cups lined with their cruel teeth closing over the inequalities of the bottom. The creature may suddenly change its mode of progression and shoot like an arrow, backward and upward. If we watch one in its passage over areas of seaweed and sand, a wonderful adaptation becomes apparent. Its color changes continually; when near sand it is of a sober brown hue, then blushes of color pass over it and the tint changes, corresponding to the seaweed or patches of pink sponge over which it swims. The way in which this is accomplished is very ingenious and loses nothing by examination. Beneath the skin are numerous cells filled with liquid pigment. When at rest these contract until they are almost invisible, appearing as very small

[11] Victor Hugo (1802-1885). A romantic French poet, novelist, and dramatist, author of *Toilers of the Sea,* an incident in which is a fight with an octopus.

specks or dots on the surface of the body. When the animal wishes to change its hue, certain muscles which radiate from these color cells are shortened, drawing the cells out in all directions until they seem confluent. It is as if the freckles on a person's face should be all joined together, when an ordinary tan would result.

10. THE DEPTHS

From bottoms ten to twenty fathoms below the surface, deeper than mortal eye can probably ever hope to reach, the dredge brings up all manner of curious things; basket starfish, with arms divided and subdivided into many tendrils, on the tips of which it walks, the remaining part converging upward like the trellis of a vine-covered summer house. Sponges of many hues must fairly carpet large areas of the deep water, as the dredge is often loaded with them. The small shore-loving ones which I photographed are in perfect health, but the camera cannot show the many tiny currents of water pouring in food and oxygen at the smaller openings, and returning in larger streams from the tall funnels on the surface of the sponge, which a pinch of carmine dust reveals so beautifully. From the deeper aquatic gardens come up great orange and yellow sponges, two and three feet in length, and around the bases of these the weird serpent stars are clinging, while crabs scurry away as the mass reaches the surface of the water.

Treasures from depths of forty and even fifty fathoms can be obtained when a trip is taken with the trawl-men. One can sit fascinated for hours, watching the hundreds of yards of line reel in, with some interesting creature on each of the thirty-seven hundred odd hooks. At times a glance down into the clear water will show a score of fish in sight at once, hake, haddock, cod, halibut, dog-fish, and perhaps an immense

"barn-door" skate, a yard or more square. This latter will hold back with frantic flaps of its great "wings," and tax all the strength of the sturdy Acadian [12] fishermen to pull it to the gunwale.

Now and then a huge "meat-rock," the fishermen's apt name for an anemone, comes up, impaled on a hook, and still clinging to a stone of five to ten pounds weight. These gigantic scarlet ones from full fifty fathoms far surpass any near shore. Occasionally the head alone of a large fish will appear, with the entire body bitten clean off, a hint of the monsters which must haunt the lower depths. The pressure of the air must be excessive, for many of the fishes have their swimming bladders fairly forced out of their mouths by the lessening of atmospheric pressure as they are drawn to the surface. When a basket starfish finds one of the baits in that sunless void far beneath our boat, he hugs it so tenaciously that the upward jerks of the reel only make him hold the more tightly.

Once in a great while the fishermen find what they call a "knob-fish" on one of their hooks, and I never knew what they meant until one day a small colony of five was brought ashore. *Boltenia,* the scientists call them, tall, queer-shaped things; a stalk six to eight inches in length, with a knob or oblong bulb-like body at the summit, looking exactly like the flower of a lady-slipper orchid and as delicately colored. This is a member of that curious family of Ascidians, which forever trembles in the balance between the higher back-boned animals and the lower division, where are classified the humbler insects, crabs, and snails. The young of *Boltenia* promises everything in its tiny backbone or notochord, but it all ends in promise, for that shadow of a great ambition withers away, and

[12] Acadian fishermen. Natives of what was once the French colony of Acadia, on the shores of the Bay of Fundy.

the creature is doomed to a lowly and vegetative life. If we soften the hard scientific facts which tell us of these dumb, blind creatures, with the humane mellowing thought of the oneness of all life, we will find much that is pathetic and affecting in their humble biographies from our point of view. And yet these cases of degeneration are far from anything like actual misfortunes, or mishaps of nature, as Buffon [13] was so fond of thinking. These creatures have found their adult mode of life more free from competition than any other, and hence their adoption of it. It is only another instance of exquisite adaptation to an unfilled niche in the life of the world.

II. EVENING AT THE SHORE

Yet another phase of enjoying the life of these northern waters; the one which comes after all the work and play of collecting is over for the day, after the last specimen is given a fresh supply of water for the night, and the final note in our journal is written. Then, as dusk falls, we make our way to the beach, ship our rudder and oars and push slowly along shore, or drift quietly with the tide. The stars may come out in clear splendor and the visual symphony of the northern lights play over the dark vault above us, or all may be obscured in lowering, leaden clouds. But the lights of the sea are never obscured—they always shine with a splendor which keeps one entranced for hours.

At night the ripples and foam of the Fundy shores seem transformed to molten silver and gold, and after each receding wave the emerald seaweed is left dripping with millions of sparkling lights, shining with a living luster which would pale the brightest gem. Each of these countless sparks is a tiny animal, as perfect in its substance and as well adapted to its

[13] Count Georges de Buffon (1707-1788). A great French naturalist.

cycle of life as the highest created being. The wonderful way in which this phosphorescence permeates everything—the jellyfish seeming elfish fireworks as they throb through the water with rhythmic beats—the fish brilliantly lighted up and plainly visible as they dart about far beneath the surface—makes such a night on the Bay of Fundy an experience to be always remembered.

Like the tints on a crescent sea beach
When the moon is new and thin,
Into our hearts high yearnings
Come welling and surging in—
Come, from the mystic ocean,
Whose rim no foot has trod—
Some of us call it longing,
And others call it God.

W. H. Carruth.[14]

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 Interest of the Seashore

1 Why do the mountains hold us spellbound?
2 What gives grandeur to the ocean?
3 Read Lord Byron's apostrophe to the ocean, *Childe Harold's Pilgrimage,* Canto IV, stanzas 179-184. Then report what reasons Byron gives for admiring the ocean.
4 What characteristics of the ocean would interest such different types of people as the scientist, the tourist, and the lover of natural beauty?
5 What is there along the shore of the sea that is worthy of study?

2 The Seashore at High Tide

6 Why did Mr. Beebe notice so many details connected with the seashore?

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[14] William Herbert Carruth (1859-1924). An American poet, author of a remarkable poem, *Evolution,* from which the stanza is taken.

7 Mr. Beebe's account of barnacles shows that he observed barnacles long and closely. Tell some of your own observations in the world of nature.

8 What does Mr. Beebe's account of mussels show concerning him?

3 The Seashore at Low Tide

9 What enabled Mr. Beebe to find on the seashore so much more than most people would notice?

10 Name and describe some of the wonders along the seashore.

4 Sea-Anemones

11 In what ways does Mr. Beebe show the spirit of experiment?

12 What shows Mr. Beebe's patient, minute observation?

5 Fish and Jelly-Fish

13 Explain how you think Mr. Beebe made his observations of jelly-fish.

6 Starfish and Sea-Urchins

14 Explain all the scientific work that you think Mr. Beebe carried on in his study of the seashore.

15 How did Mr. Beebe obtain apparatus?

16 How long, probably, did Mr. Beebe carry on work in studying the seashore?

17 With what spirit did Mr. Beebe make his observations?

18 Why are starfish wonderful?

7 Sea-Worms, Shrimps, and Prawns

19 What unusual forms of life did Mr. Beebe observe?

20 Describe some of the unusually beautiful creatures that Mr. Beebe observed.

21 Explain one of the many miracles of nature.

8 Hydroids

22 Explain the remarkable transformation that takes place in hydroids.

9 Under the Surface

23 To what lengths did Mr. Beebe go in order to learn about the wonders of the sea?

24 Describe what may be seen at the bottom of the sea, near the shore.

25 Explain what makes the bottom of the sea beautiful.

26 To what dangers did Mr. Beebe expose himself in his efforts to make accurate observations?
27 How does the squid change its color?

10 The Depths

28 What wonders are to be found in the deeper waters?
29 Explain evidences of adaptation to environment.

11 Evening at the Shore

30 In what respects is Mr. Beebe a poet?
31 In what respects is Mr. Beebe a scientist?
32 Make definite observations of something in the outdoor's world, such as clouds, trees, grass, a stream, a pond or lake, rain or snow, and report what you observe.

BOOKS FOR FURTHER READING

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THE MOON

By

GARRETT PUTMAN SERVISS

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"The imagination of mankind has never resisted the fascination of the moon."

GARRETT P. SERVISS.

GARRETT PUTMAN SERVISS
(1851-)

As a popular lecturer and writer on astronomy Garrett Putman Serviss has done much to interest people in the general facts of astronomy.

Among his books are the following: *Astronomy with an Opera Glass* (1888); *The Conquest of Mars* (1898); *The Moon Metal* (1900); *Pleasures of the Telescope* (1901); *Other Worlds* (1902); *The Moon* (1907); *Astronomy with the Naked Eye* (1908); *Curiosities of the Sky* (1909); *Round the Year with the Stars* (1910); *A Columbus of Space* (1911); *Astronomy in a Nutshell* (1912); *The Second Deluge* (1912); *Eloquence* (1912); *The Moon Maiden* (1915).

THE MOON

By Garrett Putman Serviss

Queen and huntress chaste and fair,
Now the sun is laid to sleep,
Seated in thy silver chair
State in wonted manner keep.
Hesperus entreats thy light
Goddess excellently bright.

—Ben Jonson.[1]

I. THE MOON AND IMAGINATION

THE imagination of mankind has never resisted the fascination of the moon. Under her magic spell the whole world is transformed, and every mind becomes poetical in its degree. Watch the effect upon a great ship's company when the full moon shines over the sea. It may be "the captain's night," with a brilliant ball on the promenade deck, but neither the dancing nor the small talk nor the music can overmatch the attraction of the moon, and couples will be observed withdrawing from the revelry and seeking open places on the deck where they can watch the wondrous sight of Diana[2] on her throne.

Without the presence of the moon the Grand Canal of Venice fails in its sorcery. The Parisians eagerly await the nights of the *clair de lune*[3] to assemble along the banks of the

[1] Ben Jonson (1573-1637). An English dramatist and poet.
[2] Diana. According to classical mythology, the goddess of the moon.
[3] *Clair de lune.* Moonlight.

Seine and enjoy the spectacle of their beautiful and historic river stretching its shining reaches between the bridges, while the towers of Notre Dame[4] stand bewitched in the moonlight. London's Victoria Embankment and ugly Thames become fairy scenes when the rays of the full moon touch them. What New-Yorker who has ever crossed the Brooklyn Bridge at midnight, when the moon was silvering the bay and turning the sails of distant sloops into ebon wings outspread against the brightness, can possibly erase the picture from his memory? The force of the incantation is always and everywhere the same. Who can number the songs and the poems that have been inspired by the moonlight? In the depths of the African or the Amazonian forests, or the wilds of Canada, or among the palm-ringed Pacific islands, or amid the ice and snow of the arctic and the antarctic circles, the moon is the same enchantress.

In every part of the world people have sat in the moonlight, and still sit, spinning fancies about the curious spots on that bright, round face in the sky. The legend of the Man in the Moon is as ancient and as multiform in its variations as anything in the history of human thought. In China the Man in the Moon is believed to govern marriages and to tie together with an invisible silken cord the young men and maidens whom he designs to unite in matrimony. "This," says the Reverend Timothy Harley,[5] commenting on the story in his *Moon Lore,* "must be the man of the *honey-moon,* and we shall not meet his superior in any part of the world." In Teutonic legend the Man in the Moon, carrying a bundle of sticks on his back, represents a Sabbath-breaker who met a divine being

[4] Notre Dame. A cathedral in Paris, begun in 1163.

[5] Timothy Harley. Fellow of the Royal Astronomical Society. In 1885 author of *Moon Lore.*

while cutting wood on the sacred day, and when remonstrated with laughed and said that Sunday and Monday were all the same to him. "Then stand in the moon for a perpetual Monday!" (Moonday) was the sentence instantly pronounced. Dante [6] says that the Man in the Moon is Cain. Some of our Indian tribes had a legend that the Man in the Moon was a hunter with his dog, banished to the sky for some transgression; and a British Columbian tribe, visited by Mr. William Duncan, [7] told him a story of a child that cried out in the night for water, but was neglected by its mother, whereupon the Moon suddenly appeared at the door of the lodge with a pot of water which the child eagerly seized. Then the Moon carried the child up into the sky, where its face can still be seen. The New Zealand savages said that the Man in the Moon was one who, going out in the night, stumbled and sprained his ankle, whereupon he cried for help, and lamented so loudly that at last the Moon came down and took hold of him. In his terror he seized a bush, but the Moon pulled it up by the roots and sailed back into the sky with both man and bush.

The Woman in the Moon has also been a favorite subject of myth-making. In truth, it would seem that the profile of a woman's face in the moon is more evident than any masculine eidolon [8] there. It can be seen at any time between first quarter and full moon. The face, which is bright, is turned eastward. The outlines of forehead, nose, mouth, and chin are formed by the "Sea of Showers" and the "Sea of Clouds"; the eye is indicated by one of the small, dark, oval plains near the

[6] Dante Alighieri (1265-1321). A great Italian poet, author of *Divina Commedia.*

[7] William Duncan (1832-). An English missionary called "The Apostle of Alaska." He entirely changed conditions in the Indian village of Metlakahtla, Alaska, where he lived many years.

[8] Eidolon. Image.

center of the disk, while the "Seas" of "Serenity," "Tranquillity," "Fertility," and "Nectar" constitute the hair on the top and back of the head. The great crater ring Tycho blazes like a jewel on her bosom. The Chinese call the Woman in the Moon the Fairy Queen, and imagine that they can see her palace. Even the Esquimaux have invented a legend about her, although their story relates rather to the moon's phases than to anything visible on her face. They say that the Sun and the Moon are brother and sister, and that the Sun, in a fit of anger, burned one side of his sister's face coal black. Then she ran away, and the Sun has been chasing her ever since. When the burned side of her face is towards us, she disappears. Professor Charles Frederick Hartt,[9] the geologist, found a variant of this legend among the tribes along the Amazon. The Samoan savages say that the Moon came down one evening and stole a woman named Sina while she was at work in the twilight. Sina has never been able to get back again, but she still has her mallet and the board on which she was beating out bark to make cloth. The most charming of all the moon legends is that of the Greeks, who called the moon Selene, and said that she fell in love with the beautiful youth Endymion as he lay asleep on a mountain in Elis.

> Peace, ho! the moon sleeps with Endymion,
> And would not be awaked.
> —Shakespeare's *Merchant of Venice,* Act V, Scene 1.

Mr. Harley calls attention to the fact that in English, French, Italian, Latin, and Greek the moon is feminine, but in the Teutonic languages masculine.

Equally famous with the Man in the Moon and the Woman in the Moon is the Hare in the Moon. The original of this is a

[9] Charles Frederick Hartt (1840-1878). An American geologist.

Buddhist legend. The god Sakkria, disguised as a Brahman,[10] pretended to be starving and went to the animals for help. The monkey got him a bunch of mangoes; the coot picked up a fisherman's neglected string for him; the fox stole him a pot of milk. At last the god approached the hare. "I have nothing but grass," said the hare, "and you can't eat that." "But your flesh is good," suggested the pretended Brahman. The hare assented. "Then," said the Brahman, "I'll kindle a fire at the foot of this rock and you jump off into it. That'll save me the trouble of killing you." The hare assented again, but as he leaped from the rock the god caught him in his arms, and then drew his figure in the Moon as a perpetual reminder of the excellence of self-sacrifice.

2. WORSHIP OF THE MOON

The worship of the moon extends to the most ancient dates of history. In Chaldea the principal center of moon-worship was Ur, in the land of Abraham. The Israelites, in their pagan age, adored the moon under the Assyrian name of Astarte or Ashtaroth. Some have asserted that Mount Sinai was originally consecrated to the moon. The moon was the greatest divinity of the Arabs. She was one of the gods of the Persians. The moon played a great part in the religion of India, and in China moon-worship still exists. In ancient Egypt she was Isis, the sun being Osiris. The Greeks first worshipped her under the names of Selene and Phœbe, the name Artemis (Diana), as Sir G. C. Lewis[11] thinks, being of later date. Diana and Luna were the Roman names for the moon-goddess. The moon played a conspicuous part in the rites of the Druids,

[10] Brahman. A member of the priestly caste of India.

[11] Sir George C. Lewis (1806-1863). An English statesman and scholar, author of *Enquiry into the Credibility of the Early Roman History.*

and there are traces of ancient moon-worship in popular customs still surviving in the British Isles, as well as in many parts of Europe. Among the American Indians moon-worship was widely spread. By the Aztecs she was deified under the name Meztli, and they had a Pyramid of the Moon, as well as one of the sun. In the Temple of the Sun at Cuzco [12] was a chapel consecrated to the moon, the deity held next in reverence to the sun and regarded as the mother of the Incas, the moon being both the sister and the wife of the sun.

In astrology the moon, of course, makes a great figure, and as she passes so rapidly through the signs of the zodiac [13] her influence upon the planets is described as very variable. When "well affected" she bestows good qualities, according to Lilly, but even at the best a "moon person" is apt to be unsteady and inclined to flit about. When she is "ill affected" the moon makes bad characters. As Venus is said to bestow dimples, so the moon, it is averred, usually makes "one eye a little larger than the other" in her subjects.

3. THE MOON AS A VISIBLE OBJECT

The strange spots on the moon, that have given rise to so many legends, first had their true character revealed when Galileo,[14] in 1610, aimed his telescope at her. They turned out to be mountains, hills, and plains. "It is just like the earth," he declared. But the assertion, often made, that Galileo believed the moon to be inhabited is erroneous. In a letter written in 1616, and quoted by Mr. Fahie [15] in his *Life,* Galileo distinctly states his belief that it is impossible for the moon to be inhabited, and he gives substantially the same reasons that

[12] Cuzco. The ancient city of the Incas in Peru.
[13] Zodiac. An imaginary zone encircling the heavens.
[14] Galileo (1564-1642). A great Italian astronomer.
[15] John Joseph Fahie. Author of *Galileo: His Life and Work* (1903).

would be given to-day—*viz.*, the absence of water and the lack of rapid succession of day and night on her surface. The sunlight takes two weeks to creep over the face of the moon, and day and night there are each a fortnight in length. Moreover, as we now know, there is virtually no air on the moon. Yet the moon is "of the earth, earthy." When Addison[16] wrote:

> Soon as the evening shades prevail
> The moon takes up the wondrous tale,
> And nightly to the listening earth
> Proclaims the story of her birth,

he did not in the least suspect what the story was that the moon so insistently repeated. It was left for Professor George Darwin[17] and mathematical physics to unfold that story, which is one of the most wonderful in the whole domain of astronomy. Put into a few words, this story avers that the moon is the child of the earth, born by violence, under the stress of forces generated by a rapid rotation of the original single viscid mass, combined with tidal action emanating from the sun. In the constellation Vulpecula there is a nebula which shows a similar process of division now going on. Two enormous masses are seen in apparent swift rotation, while their whole substance has been whirled out into an hour-glass or dumb-bell shape. After the separation was once effected, the moon retired from the earth under the effects of "tidal friction," a subject too technical to be discussed here. But if she carried air and water with her when she parted from her mother earth, what has become of them? According to one opinion, they have been absorbed into her rocks as she cooled

[16] Joseph Addison (1672-1719). An English essayist and poet.
[17] George Darwin (1845-1912). An English physicist and astronomer, a son of Charles Darwin.

off. The relics of frightful volcanic activity on the moon seem conclusive evidence that there was once water and fire there. According to another opinion, the slight mass of the moon (one-eightieth that of the earth) prevented her from permanently retaining the gaseous and volatile elements. Whatever the cause, the fact remains that no bodies of water, and no atmosphere resembling ours, exist to-day on the moon. Yet her great plains strikingly resemble the beds of dried-up oceans.

As a telescopic object the moon takes the first rank. The slightest magnification begins to reveal the marvellous picturesqueness of her broken landscapes, and with higher powers the spectacles that she presents are indescribable in their weird magnificence. Although she is only 2100 miles in diameter, her mountains, and particularly her "craters," are mightier than those of the earth.

Everybody knows, of course, why the moon changes shape as she travels around the earth. These phases are simply due to the change in the extent of the sun-illuminated surface visible to us. When she is between the sun and the earth, she disappears; when she emerges on the east of the sun, she appears as a thin crescent in the western sky, only a narrow rim of the illuminated half being then visible to us; when she reaches a point at right angles to the direction of the sun, half of the illuminated side appears; when she is opposite to the sun she assumes the full phase, because then the whole of her illuminated side is towards the earth. As she goes round she always keeps the same side towards us, so that we know nothing, except by inference, of the other side of the moon. This peculiarity of the moon's rotation is believed to be due to the braking action of the tides raised by the attraction of the earth when the moon was yet in a viscid state.

THE CRATERS OF THE MOON
Colossal Mountain Masses Poised Before Our Eyes

4. THE MOON AND ECLIPSES

The moon both causes and suffers eclipses. When she passes exactly between the earth and the sun, the latter is hidden behind her opaque globe, and we have a solar eclipse—one of the most interesting of all astronomical phenomena, on account of the marvellous streamers of light, called the corona, which then appear surrounding the eclipsed sun, and extending away, in some cases, millions of miles. When the moon passes the earth on the side opposite to the sun—in other words, when she is a full moon—she comes at certain times almost exactly in line with the two, and then she enters the shadow of the earth and is herself eclipsed. Eclipses of the sun are very rare phenomena at any particular place on the earth, because the moon's shadow is reduced almost to a point before it reaches the earth, from her average distance of 239,000 miles, and it is only within the shadow that the sun appears eclipsed. The orbit of the moon around the earth is continually shifting its place a little, and so the point of her shadow does not reach the earth at the same place in successive eclipses. Eclipses of the moon are more frequently seen, because the earth's shadow, being much larger than the moon's, completely buries the latter when she passes into it, so that the moon can then be seen eclipsed from all places on the earth above whose horizon she happens to be at the moment.

An eclipse of the moon is very interesting to watch, because of the curious reddish tint which the face of the moon usually assumes when she is within the earth's shadow. This is due to the refraction of light by our atmosphere around the edge of the globe; and this light, being bent into the shadow, reaches the moon, and produces a partial illumination there. It follows that if we could be upon the moon during such an eclipse

we should see the huge black globe of the earth completely covering the sun and surrounded with a brilliant ring of reddish light. At times when the atmosphere of the earth is choked with clouds, the moon almost disappears during an eclipse, because then the refraction is prevented by the clouds.

The primary reason why there is not an eclipse of the sun at every new moon, and an eclipse of the moon at every full moon, is because the moon's orbit is inclined to the plane of the ecliptic, and ordinarily she passes above or below the sun in the one case, and above or below the conical shadow of the earth in the other case. The greatest number of eclipses that can occur in a year is seven, five of the sun and two of the moon; the least number is two, both of the sun. On the average four or five eclipses occur every year, more of the sun than of the moon, but, as already explained, eclipses of the sun are visible from only very limited areas on the earth, and the path of the shadow seldom falls in a convenient place for observation. Some solar eclipses are annular—*i. e.,* they occur at times when the moon is in the more distant part of her orbit, and the point of her shadow falls short of the earth. Then a bright rim of the solar disk appears surrounding the black globe of the moon. Total eclipses of the sun appear as partial eclipses to those who are situated within about two thousand miles of the edge of the moon's shadow. So, too, the moon may be partially eclipsed by passing through the edge of the earth's shadow.

Eclipses have played an astonishing part in history. The total obscuration of the sun in broad day is a phenomenon especially calculated to awaken superstitious terror, and accordingly we find that solar eclipses have generally been regarded with more fear and awe than lunar ones. It is not too much to say that, in the ages when the movements of the celestial

bodies were not understood, the course of the history of nations was sometimes changed by the passage of the moon across the sun's face. Battles were stopped, the march of armies was arrested, treaties were dictated by the terror inspired by an unexpected eclipse. Since eclipses are phenomena that can be predicted with almost absolute exactitude centuries in advance, it is easy, from our knowledge of the moon's motion, to trace her course backward as well as forward, and thus eclipses occurring thousands of years ago, and recorded by the uncritical analysts of those times, have enabled modern astronomers to fix disputed dates in history. Herodotus [18] records the fact that a battle between the Medes [19] and Lydians [20] was interrupted by an eclipse of the sun. Calculation shows that this eclipse must have occurred on May 28th in the year 585 B.C.

A curious point in the history of the celebrated Five Nations, occupying central New York at the time of the arrival of the white men, is connected with an eclipse. These Indians had a tradition that a great war between the Mohawks and the Senecas was averted by the interposition of Heaven. Some young Seneca warriors, bent on winning fame for themselves, went, in a time of peace, into the land of the Mohawks and made captive a number of girls who were at work in the cornfields. The captives were taken to Canandaigua. Their arrival caused consternation among the Senecas, whose chiefs knew well the terrible vengeance that the Mohawks would exact. Still, the Senecas also were a proud people, and when swift runners arrived demanding a humiliating submission, the Senecas responded with open defiance, and resolved to meet

[18] Herodotus (About 484-424 B.C.). A great Greek historian.

[19] Medes. The ancient inhabitants of what is now Persia and neighboring lands.

[20] Lydians. The ancient inhabitants of parts of Asia Minor bordering on the Ægean Sea.

the Mohawks in battle. A host of Mohawk warriors, thirsting for vengeance, hurried on the forest trails to Canandaigua, and the hostile ranks were about to close in deadly contest when one of the Mohawk girls cried out:

"See! the Great Spirit is angry!"

She pointed to the sky, and, all eyes following hers, they saw the sun in heaven beginning to darken. Swiftly its light was withdrawn and night fell upon the lake and the forest. The warriors of both tribes dropped to their knees, and then an aged sachem of the Senecas called for the peace-pipe. As it passed from lip to lip, the darkness lightened, the sun slowly reappeared, and in a short time his smiling face was again bent down upon his red children. The captives were surrendered, reparation was made, and the Mohawks, with full quivers, marched back to their valley home. The late Professor Lewis Swift[21] showed that a total eclipse of the sun was visible in central and western New York on June 28, 1451, and this fact has been regarded as affirming the historic accuracy of the Indian tradition, as well as fixing a date for the event.

On the other hand, lunar eclipses sometimes caused great terror. Plutarch,[22] in his *Life of Nicias*,[23] has a curious story in point. When the Athenian army, baffled before Syracuse,[24] was about to embark for home, there happened an eclipse of the moon, "at which," says Plutarch, "Nicias and all the rest were struck with a great panic, either through ignorance or superstition. As for an eclipse of the sun, which happens at the conjunction, even the common people had some idea

[21] Lewis Swift (1820-1913). An American astronomer.
[22] Plutarch (About 46 A.D.). A Greek historian.
[23] Nicias (About the Fifth Century B.C.). A Greek painter.
[24] Syracuse. The ancient capital of the Province of Syracuse, on the island of Ortygia, near the east of Sicily.

of its being caused by the interposition of the moon. But they could not easily form a conception by the interposition of what body the moon, when at the full, should lose her light and assume such a variety of colors. They looked upon it, therefore, as a strange and preternatural phenomenon, a sign by which the gods announced some great calamity."

The reader will observe that even in their terror the frightened soldiers did not fail to note the curious coloration of the eclipsed moon, due, as we now know, to the refraction of light by the earth's atmosphere.

But eclipses were not universally considered by the ancients as miraculous events. Better instructed minds perceived that there was a regular recurrence of these phenomena, and that they were connected with the movements of the moon. Thales [25] is said to have predicted the solar eclipse of 585 B.C., and Hipparchus [26] ascertained the general law of the moon's motions. Even the Chaldeans knew that eclipses recur in a certain order during every successive period of eighteen years, and to this period was given the name Saros.

5. THE MOON AND THE EARTH

The revolution of the moon naturally gave rise to the division of time into months. All would have been very simple if the moon's time of revolution had been an exact fraction of the year. Then every year would have had precisely twelve lunar months. But the time from one new moon to the next is about twenty-nine and a half days, and the problem that the calendar-makers had to solve was how to adjust this so as to

[25] Thales (640-546 B.C.). A Greek philosopher and astronomer.

[26] Hipparchus (160-125 B.C.). A Greek astronomer, the founder of scientific study of the heavens.

give a fixed number of months to the year. This is not the place to enter into a discussion of the difficult subject of the settling of the calendar, which is dealt with in ordinary school-books of astronomy, but it may be remarked that as a result of the necessary adjustments new and full moons may occur at any time in the course of our present months. So the name month (undoubtedly derived from the same root as moon, just as the original idea of a month was suggested by the moon's period of revolution) no longer possesses more than a historic connection with the monthly traveller through the sky.

Another, and practically a much more important, relation of the moon to the earth is seen in the tides. Both the sun and the moon raise tides in the ocean, but those of the moon are much the higher, simply because she is so near. This is a technical subject beyond the intended scope of our book, but it is interesting to remember that but for the tides produced by the moon some of the most important harbors on the earth would be shut against deep-draught ships.

Those who look at the new moon often see the whole face of her globe faintly illuminated, the bright crescent seeming to border it like a silver handle. Even some of the ancients recognized the fact that this light comes from the earth. At such times the earth hangs in the lunar sky as a round, gleaming ball of portentous size, many times larger than the full moon looks to us, and the faint illumination that we see on the part of the moon hidden from the sun is earth light.

In her course through the zodiac—for the moon follows, practically, the same path as the planets—she often passes over, or occults, stars, and occasionally planets. These phenomena are interesting to observe with the naked eye, if the star occulted happens to be a bright one. If the occultation occurs

near the time of new moon, or first quarter, the star disappears behind the dark part of the moon as if it had been snuffed out. When the moon is crescent-shaped the star, just before its disappearance, often looks as if it were *inside* the horns of the moon, and this appearance is so deceptive that some people think that the moon really can carry a star in her arms. The monthly progress of the moon through the zodiacal constellations, and her conjunctions with the planets and the first and second magnitude stars, or with clusters like the Pleiades and the Hyades, are among the most captivating sights that astronomy with the naked eye has to offer.

The idea that the moon exercises an important influence on the weather has no scientific foundation, all attempts to establish such an influence having failed. So, too, the supposed influence of the moon on the sap in trees, and on the growth of plants has no basis except that of a wide-spread popular belief.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The Moon and Imagination

1 What explains the moon's fascinating power?
2 Why have so many legends been based upon the moon?
3 Tell some of the legends concerning the moon.

2 Worship of the Moon

4 What part has the moon played in religion?

3 The Moon as a Visible Object

5 What are the spots on the moon?
6 Why do we think that there is no life on the moon?
7 What may have been the origin of the moon?

8 What theories explain the lack of air and of water on the moon?
9 Why does the moon appear to change shape?
10 How much of the moon do we see?

4 The Moon and Eclipses

11 What are the causes of eclipses?
12 Why are eclipses of the moon more frequent than eclipses of the sun?
13 What facts establish the number of eclipses that occur in a year?
14 Explain the nature and the causes of annular eclipses of the sun.
15 What historical events have been affected by eclipses?
16 How does the study of eclipses aid historians?
17 What did the ancients know about eclipses?

5 The Moon and the Earth

18 Why has the term "month" lost its original meaning?
19 How does the moon affect tides?
20 What is "earth light"?
21 Explain "occultation."
22 Does the moon affect weather, or the growing of crops?
23 Tell some of your own observations of the moon.
24 Look at the moon through a good field glass or telescope. Report what you observe.

BOOKS FOR FURTHER READING

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THE IMPORTANCE OF DUST

By

ALFRED RUSSEL WALLACE

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"The overwhelming importance of the small things, and even of the despised things, of our world has never, perhaps, been so strikingly brought home to us as in these recent investigations into the wide-spread and far-reaching beneficial influences of atmospheric dust."

ALFRED RUSSEL WALLACE.

ALFRED RUSSEL WALLACE
(1823-1913)

As biologist, traveller, explorer, collector, and author, Alfred Russel Wallace lived a vigorous life. His greatest work was the origination, independently of Charles R. Darwin, of the theories of natural selection and of the survival of the fittest: "Those that prolong their existence can only be the most perfect in health and vigor. . . . The weakest and least perfectly organized must always succumb."

While a boy Alfred R. Wallace studied botany. Later he collected beetles. At 25 he went to South America, where he studied tropical growths. At 30 he published his first book of travels. From 31 to 39 Mr. Wallace explored the Malay Islands, Sumatra, Java, Borneo, the Celebes, the Moluccas, Timor, New Guinea, and the Aru and Ké Islands, and in 1869 published an account of his work. While suffering with fever in the Molucca Islands, Mr. Wallace originated the theory of the survival of the fittest.

In England, where the scientist spent the rest of his life, except for occasional journeys, he continued scientific study, wrote, and took part in directing public thought.

Alfred Russel Wallace published his last book at the age of 89, and he lived to the age of 90. To the last he was interested in nature, and tenderly cared for his English garden with its thousand species of plants.

His important books are: *Travels on the Amazon and Rio Negro* (1853); *Palm Trees of the Amazon* (1854); *The Malay Archipelago* (1869); *Contributions to the Theory of Natural Selection* (1871); *Geographical Distribution of Animals* (1876); *Tropical Nature and Other Essays* (1878); *Island Life* (1880); *Miracles and Modern Spiritualism* (1881); *Land Nationalization* (1882); *Forty-five Years of Registration Statistics* (1885); *The Wonderful Century* (1899); *Studies Scientific and Social* (1900); *Man's Place in the Universe* (1903); *My Life* (1905); *Is Mars Habitable?* (1908); *The World and Life* (1910); *Social Environment and Moral Progress* (1912).

THE IMPORTANCE OF DUST

By Alfred Russel Wallace

When the lamp is shattered,
The light in the dust lies dead;
When the cloud is scattered,
The rainbow's glory is shed.

—Shelley.[1]

How beautiful is the rain!
After the dust and heat,
In the broad and fiery street,
In the narrow lane,
How beautiful is the rain!

—Longfellow.[2]

I. THE BLUE OF THE SKY AND OF THE SEA

THE majority of persons, if asked what were the uses of dust, would reply that they did not know it had any, but they were sure it was a great nuisance. It is true that dust, in our towns and in our houses is often not only a nuisance but a serious source of disease; while in many countries it produces ophthalmia,[3] often resulting in total blindness. Dust, however, as it is usually perceived by us, is, like dirt, only matter in the wrong place, and whatever injurious or disagreeable effects it produces are largely due to our own dealings with nature. So soon as we dispense with horse-power and adopt purely mechanical means of traction and conveyance,

[1] Percy Bysshe Shelley (1792-1822). A noted English poet.
[2] Henry Wadsworth Longfellow (1807-1882). A great American poet.
[3] Ophthalmia. A serious inflammation of the eyes.

we can almost wholly abolish disease-bearing dust from our streets, and ultimately from all our highways; while another kind of dust, that caused by the imperfect combustion of coal, may be got rid of with equal facility so soon as we consider pure air, sunlight, and natural beauty to be of more importance to the population as a whole than are the prejudices or the vested interests of those who produce the smoke.

But though we can thus minimize the dangers and the inconveniences arising from the grosser forms of dust, we cannot wholly abolish it; and it is, indeed, fortunate we cannot do so, since it has now been discovered that it is to the presence of dust we owe much of the beauty, and perhaps even the very habitability, of the earth we live upon. Few of the fairy tales of science are more marvellous than these recent discoveries as to the varied effects and important uses of dust in the economy of nature.

The question why the sky and the deep ocean are both blue did not much concern the earlier physicists. It was thought to be the natural color of pure air and water, so pale as not to be visible when small quantities were seen, and only exhibiting its true tint when we looked through great depths of atmosphere or of organic water. But this theory did not explain the familiar facts of the gorgeous tints seen at sunset and sunrise, not only in the atmosphere and on the clouds near the horizon, but also in equally resplendent hues when the invisible sun shines upon Alpine peaks and snowfields. A true theory should explain all these colors, which comprise almost every tint of the rainbow.

The explanation was found through experiments on the visibility or non-visibility of air, which were made by the late Professor Tyndall about the year 1868. Everyone has seen the floating dust in a sunbeam when sunshine enters a partially

darkened room; but it is not generally known that if there was absolutely no dust in the air the path of the sunbeam would be totally black and invisible, while if only very little dust was present in very minute particles the air would be as blue as a summer sky.

This was proved by passing a ray of electric light lengthways through a long glass cylinder filled with air of varying degrees of purity as regards dust. In the air of an ordinary room, however clean and well ventilated, the interior of the cylinder appears brilliantly illuminated. But if the cylinder is exhausted and then filled with air which has passed slowly through a fine gauze of intensely heated platinum wire, so as to burn up all the floating dust particles, which are mainly organic, the light will pass through the cylinder without illuminating the interior, which, viewed laterally, will appear as if filled with a dense black cloud. If, now, more air is passed into the cylinder through the heated gauze, but so rapidly that the dust particles are not wholly consumed, a slight blue haze will begin to appear, which will gradually become a pure blue, equal to that of a summer sky. If more and more dust particles are allowed to enter, the blue becomes paler, and gradually changes to the colorless illumination of the ordinary air.

The explanation of these phenomena is that the number of dust particles in ordinary air is so great that they reflect abundance of light of all wave-lengths, and thus cause the interior of the vessel containing them to appear illuminated with white light. The air which has passed slowly over white-hot platinum has had the dust particles destroyed, thus showing that they were almost wholly of organic origin, which is also indicated by their extreme lightness, causing them to float permanently in the atmosphere. The dust being thus got rid of,

and pure air being entirely transparent, there is nothing in the cylinder to reflect the light which is sent through its center in a beam of parallel rays, so that none of it strikes against the sides; hence the inside of the cylinder appears absolutely dark. But when all the larger dust particles are wholly or partially burnt, so that only the very smallest fragments remain, a blue light appears, because these are so minute as to reflect chiefly the more refrangible rays, which are of shorter wave-length—those at the blue end of the spectrum, which are thus scattered in all directions, while the red and yellow rays pass straight on as before.

We have seen that the air near the earth's surface is full of rather coarse particles which reflect all the rays, and which therefore produce no one color. But higher up the particles necessarily become smaller and smaller, since the comparatively rare atmosphere will only support the very smallest and lightest. These exist throughout a great thickness of air, perhaps from one mile to ten miles high or even more, and blue or violet rays being reflected from the innumerable particles in this great mass of air, which is nearly uniform in all parts of the world as regards the presence of minute dust particles, produce the constant and nearly uniform tint we call sky-blue. A certain amount of white or yellow light is no doubt reflected from the coarser dust in the lower atmosphere, and slightly dilutes the blue and renders it not quite so deep and pure as it otherwise would be. This is shown by the increasing depth of the sky-color when seen from the tops of lofty mountains, while from the still greater heights attained in balloons the sky appears of a blue-black color, the blue reflected from the comparatively small amount of dust particles being seen against the intense black of stellar space. It is for the same reason that the "Italian skies" are of so rich a blue, because the Medi-

terranean Sea on one side and the snowy Alps on the other do not furnish so large a quantity of atmospheric dust in the lower strata of air as in less favorably situated countries, thus leaving the blue reflected by the more uniformly distributed fine dust of the higher strata undiluted. But these Mediterranean skies are surpassed by those of the central Pacific ocean, where, owing to the small area of land, the lower atmosphere is more free from coarse dust than any other part of the world.

If we look at the sky on a perfectly fine summer's day, we shall find that the blue color is the most pure and intense overhead, and when looking high up in a direction opposite to the sun. Near the horizon it is always less bright, while in the region immediately round the sun it is more or less yellow. The reason of this is that near the horizon we look through a very great thickness of the lower atmosphere, which is full of the larger dust particles reflecting white light, and this dilutes the pure blue of the higher atmosphere seen beyond. And in the vicinity of the sun a good deal of the blue light is reflected back into space by the finer dust, thus giving a yellowish tinge to that which reaches us reflected chiefly from the coarse dust of the lower atmosphere. At sunset and sunrise, however, this last effect is greatly intensified, owing to the great thickness of the strata of air through which the light reaches us. The enormous amount of this dust is well shown by the fact that, then only, we can look full at the sun, even when the whole sky is free from clouds and there is no apparent mist. But the sun's rays then reach us after having passed, first, through an enormous thickness of the higher strata of the air, the minute dust of which reflects most of the blue rays away from us, leaving the complementary yellow light to pass on. Then, the somewhat coarser dust reflects the green rays, leaving a more orange colored light to pass on; and finally some of the yellow

is reflected, leaving almost pure red. But owing to the constant presence of air currents, arranging both the dust and vapor in strata of varying extent and density, and of high or low clouds, which both absorb and reflect the light in varying degrees, we see produced all those wondrous combinations of tints and those gorgeous ever-changing colors, which are a constant source of admiration and delight to all who have the advantage of an uninterrupted view to the west, and who are accustomed to watch for these not unfrequent exhibitions of nature's kaleidoscopic[4] color-painting. With every change in the altitude of the sun the display changes its character; and most of all when it has sunk below the horizon, and, owing to the more favorable angles, a larger quantity of the colored light is reflected toward us. Especially when there is a certain amount of cloud is this the case. These, so long as the sun was above the horizon, intercepted much of the light and color; but, when the great luminary has passed away from our direct vision, his light shines more directly on the under sides of all the clouds and air strata of different densities; a new and more brilliant light flushes the western sky, and a display of gorgeous ever-changing tints occurs which are at once the delight of the beholder and the despair of the artist. And all this unsurpassable glory we owe to—dust!

A remarkable confirmation of this theory was given during the two or three years after the great eruption of Krakatoa,[5] near Java. The volcanic *débris* was shot up from the crater many miles high, and the heavier portion of it fell upon the sea for several hundred miles around, and was found to be

[4] Kaleidoscopic. A kaleidoscope is an instrument that reflects many beautiful, changing forms and colors.

[5] Krakatoa. In 1883 a great volcanic eruption on the little island of Krakatoa between Java and Sumatra caused the death of over 30,000 people.

mainly composed of very thin flakes of volcanic glass. Much of this was of course ground to impalpable dust by the violence of the discharge, and was carried up to a height of many miles. Here it was caught by the return current of air continually flowing northward and southward above the equatorial zone; and as these currents reach the temperate zone where the surface rotation of the earth is less rapid they continually flow eastward, and the fine dust was thus carried at a great altitude completely round the earth. Its effects were traced some months after the eruption in the appearance of brilliant sunset glows of an exceptional character, often flushing with crimson the whole western half of the visible sky. These glows continued in diminishing splendor for about three years; they were seen all over the temperate zone, and it was calculated that, before they finally disappeared, some of this fine dust must have travelled three times round the globe.

The same principle is thought to explain the exquisite blue color of the deep seas and oceans and of many lakes and springs. Absolutely pure water, like pure air, is colorless, but all seas and lakes, however clear and translucent, contain abundance of very finely divided matter, organic or inorganic, which, as in the atmosphere, reflects the blue rays in such quantity as to overpower the white or colored light reflected from the fewer and more rapidly sinking particles of larger size. The oceanic dust is derived from many sources. Minute organisms are constantly dying near the surface, and their skeletons, or fragments of them, fall slowly to the bottom. The mud brought down by rivers, though it cannot be traced on the ocean floor more than about 150 miles from land, yet no doubt furnishes many particles of organic matter which are carried by surface currents to enormous distances and are ultimately dissolved before they reach the bottom. A more impor-

tant source of finely divided matter is to be found in volcanic dust which, as in the case of Krakatoa, may remain for years in the atmosphere, but which must ultimately fall upon the surface of the earth and ocean. This can be traced in all the deep-sea oozes. Finally there is meteoric dust, which is continually falling to the surface of the earth, but in such minute quantities and in such a finely-divided state that it can only be detected in the oozes of the deepest oceans, where both inorganic and organic *débris* is almost absent.

The blue of the ocean varies in different parts from a pure blue somewhat lighter than that of the sky, as seen about the northern tropic in the Atlantic, to a deep indigo tint, as seen in the north temperate portions of the same ocean: due, probably, to differences in the nature, quantity, and distribution of the solid matter which causes the color. The Mediterranean, and the deeper Swiss lakes are also blue of various tints, due also to the presence of suspended matter, which Professor Tyndall [6] thought might be so fine that it would require ages of quiet subsidence to reach the bottom. All the evidence goes to show, therefore, that the exquisite blue tints of sky and ocean, as well as all the sunset hues of sky and cloud, of mountain peak and alpine snows, are due to the finer particles of that very dust which, in its coarser forms, we find so annoying and even dangerous.

2. MIST, CLOUDS, AND RAIN

But if this production of color and beauty were the only useful function of dust, some persons might be disposed to dispense with it in order to escape its less agreeable effects. It has, however, been recently discovered that dust has another part to play in nature; a part so important that it is doubtful

[6] See the Introduction to Essay Number 4, *Niagara.*

whether we could even live without it. To the presence of dust in the higher atmosphere we owe the formation of mists, clouds, and gentle beneficial rains, instead of waterspouts and destructive torrents.

It is barely twenty years ago since the discovery was made, first in France by Coulier and Mascart,[7] but more thoroughly worked out by Mr. John Aitken[8] in 1880. He found that if a jet of steam is admitted into two large glass receivers,—one filled with ordinary air, the other with air which has been filtered through cotton wool so as to keep back all particles of solid matter,—the first will be instantly filled with condensed vapor in the usual cloudy form, while the other vessel will remain quite transparent. Another experiment was made, more nearly reproducing what occurs in nature. Some water was placed in the two vessels prepared as before. When the water had evaporated sufficiently to saturate the air the vessels were slightly cooled, when a dense cloud was at once formed in the one while the other remained quite clear. These experiments, and many others, showed that the mere cooling of vapor in air will not condense it into mist clouds or rain, unless *particles of solid matter* are present to form *nuclei* upon which condensation can begin. The density of the cloud is proportionate to the number of the particles; hence the fact that the steam issuing from the safety-valve or the chimney of a locomotive forms a dense white cloud shows that the air is really full of dust particles, most of which are microscopic but none the less serving as centres of condensation for the vapor. Hence, if there were no dust in the air, escaping steam would remain invisible; there would be no clouds in the sky; and the

[7] Eleuthere Mascart (1837-1908). A French physicist, associated with M. Coulier, a contemporary French physicist, in important investigations.

[8] John Aitken (1839-1919). A Scotch physicist who made an especial study of dust.

vapor in the atmosphere, constantly accumulating through evaporation from seas and oceans and from the earth's surface, would have to find some other means of returning to its source.

One of these modes would be the deposition of dew, which is itself an illustration of the principle that vapor requires solid or liquid surfaces to condense upon; hence dew forms more readily and more abundantly on grass, on account of the numerous centres of condensation it affords. Dew, however, is now formed only on clear cold nights after warm or moist days. The air near the surface is warm and contains much vapor, though below the point of saturation. But the innumerable points and extensive surfaces of grass radiate heat quickly, and becoming cool, lower the temperature of the adjacent air, which then reaches saturation point and condenses the contained vapor on the grass. Hence, if the atmosphere at the earth's surface became super-saturated with aqueous vapor, dew would be continuously deposited, especially on every form of vegetation, the result being that everything, including our clothing, would be constantly dripping wet. If there were absolutely no particles of solid matter in the upper atmosphere, all the moisture would be returned to the earth in the form of dense mists, and frequent and copious dews, which in forests would form torrents of rain by the rapid condensation on the leaves. But if we suppose that solid particles were occasionally carried higher up through violent winds or tornadoes, then on those occasions the super-saturated atmosphere would condense rapidly upon them, and while falling would gather almost all the moisture in the atmosphere in that locality, resulting in masses or sheets of water, which would be so ruinously destructive by the mere weight and impetus of their fall that it is doubtful whether they would not render the earth almost wholly uninhabitable.

The chief mode of discharging the atmospheric vapor in the absence of dust would, however, be by contact with the higher slopes of all mountain ranges. Atmospheric vapor, being lighter than air, would accumulate in enormous quantities in the upper strata of the atmosphere, which would be always super-saturated and ready to condense upon any solid or liquid surfaces. But the quantity of land comprised in the upper half of all the mountains of the world is a very small fraction of the total surface of the globe, and this would lead to very disastrous results. The air in contact with the higher mountain slopes would rapidly discharge its water, which would run down the mountain sides in torrents. This condensation on every side of the mountains would leave a partial vacuum which would set up currents from every direction to restore the equilibrium, thus bringing in more super-saturated air to suffer condensation and add its supply of water, again increasing the indraught of more air. The result would be that winds would be constantly blowing toward every mountain range from all directions, keeping up the condensation and discharging, day and night and from one year's end to another, an amount of water equal to that which falls during the heaviest tropical rains. The whole of the rain that now falls over the whole surface of the earth and ocean, with the exception of a few desert areas, would then fall only on rather high mountains or steep isolated hills, tearing down their sides in huge torrents, cutting deep ravines, and rendering all growth of vegetation impossible. The mountains would therefore be so devastated as to be uninhabitable, and would be equally incapable of supporting either vegetable or animal life.

But this constant condensation on the mountains would probably check the deposit on the lowlands in the form of dew, because the continual up-draught toward the higher slopes

would withdraw almost the whole of the vapor as it rose from the oceans and other water-surfaces, and thus leave the lower strata over the plains almost or quite dry. And if this were the case there would be no vegetation, and therefore no animal life, on the plains and lowlands, which would thus be all arid deserts cut through by the great rivers formed by the meeting together of the innumerable torrents from the mountains.

Now, although it may not be possible to determine with perfect accuracy what would happen under the supposed condition of the atmosphere, it is certain that the total absence of dust would so fundamentally change the meteorology of our globe as, not improbably, to render it uninhabitable by man, and equally unsuitable for the larger portion of its existing animal and vegetable life.

3. THE BENEFICENT EFFECTS OF DUST

Let us now briefly summarize what we owe to the universality of dust, and especially to that most finely divided portion of it which is constantly present in the atmosphere up to the height of many miles. First of all it gives us the pure blue of the sky, one of the most exquisitely beautiful colors in nature. It gives us also the glories of the sunset and the sunrise, and all those brilliant hues seen in high mountain regions. Half the beauty of the world would vanish with the absence of dust. But, what is far more important than the color of sky and beauty of sunset, dust gives us also diffused daylight, or skylight, that most equable, and soothing, and useful, of all illuminating agencies. Without dust the sky would appear absolutely black, and the stars would be visible even at noonday. The sky itself would therefore give us no light. We should have bright glaring sunlight or intensely dark shadows, with hardly any halftones. From this cause alone the world would be so totally

different from what it is that all vegetable and animal life would probably have developed into very different forms, and even our own organization would have been modified in order that we might enjoy life in a world of such harsh and violent contrasts.

In our houses we should have little light except when the sun shone directly into them, and even then every spot out of its direct rays would be completely dark, except for light reflected from the walls. It would be necessary to have windows all round and the walls all white; and on the north side of every house a high white wall would have to be built to reflect the light and prevent that side from being in total darkness. Even then we should have to live in a perpetual glare, or shut out the sun altogether and use artificial light as being a far superior article.

Much more important would be the effects of a dustfree atmosphere in banishing clouds, or mist, or the "gentle rain of heaven," and in giving us in their place perpetual sunshine, desert lowlands, and mountains devastated by unceasing floods and raging torrents, so as, apparently, to render all life on the earth impossible.

There are a few other phenomena, apparently due to the same general causes, which may here be referred to. Everyone must have noticed the difference in the atmospheric effects and general character of the light in spring and autumn, at times when the days are of the same length, and consequently when the sun has the same altitude at corresponding hours. In spring we have a bluer sky and greater transparency of the atmosphere; in autumn, even on very fine days, there is always a kind of yellowish haze, resulting in a want of clearness in the air and purity of color in the sky. These phenomena are quite intelligible when we consider that during winter less dust is

formed, and more is brought down to the earth by rain and snow, resulting in the transparent atmosphere of spring, while exactly opposite conditions during summer bring about the mellow autumnal light. Again, the well-known beneficial effects of rain on vegetation, as compared with any amount of artificial watering, though, no doubt, largely due to the minute quantity of ammonia which the rain brings down with it from the air, must yet be partly derived from the organic or mineral particles which serve as the nuclei of every raindrop, and which, being so minute, are more readily dissolved in the soil and appropriated as nourishment by the roots of plants.

It will be observed that all these beneficial effects of dust are due to its presence in such quantities as are produced by natural causes, since both gentle showers as well as ample rains and deep blue skies are present throughout the vast equatorial forest districts, where dust-forming agencies seem to be at a minimum. But in all densely-populated countries there is an enormous artificial production of dust—from our ploughed fields, from our roads and streets, where dust is continually formed by the iron-shod hoofs of innumerable horses, but chiefly from our enormous combustion of fuel pouring into the air volumes of smoke charged with unconsumed particles of carbon. This superabundance of dust, probably many times greater than that which would be produced under the more natural conditions which prevailed when our country was more thinly populated, must almost certainly produce some effect on our climate; and the particular effect it seems calculated to produce is the increase of cloud and fog, but not necessarily any increase of rain. Rain depends on the supply of aqueous vapor by evaporation; on temperature, which determines the dew point; and on changes in barometric pressure, which determine the winds. There is probably always and everywhere enough

atmospheric dust to serve as centres of condensation at considerable altitudes, and thus to initiate rainfall when the other conditions are favorable; but the presence of increased quantities of dust at the lower levels must lead to the formation of denser clouds, although the minute water-vesicles cannot descend as rain, because, as they pass down into warmer and dryer strata of air, they are again evaporated.

Now, there is much evidence to show that there has been a considerable increase in the amount of cloud, and consequent decrease in the amount of sunshine, in all parts of our country. It is an undoubted fact that in the Middle Ages England was a wine-producing country, and this implies more sunshine than we have now. Sunshine has a double effect, in heating the surface soil and thus causing more rapid growth, besides its direct effect in ripening the fruit. This is well seen in Canada, where, notwithstanding a six months' winter of extreme severity, vines are grown as bushes in the open ground, and produce fruit equal to that of our ordinary greenhouses. Some years back one of our gardening periodicals obtained from gardeners of forty or fifty years' experience a body of facts clearly indicating a comparatively recent change of climate. It was stated that in many parts of the country, especially in the north, fruits were formerly grown successfully and of good quality in gardens where they cannot be grown now; and this occurred in places sufficiently removed from manufacturing centers to be unaffected by any direct deleterious influence of smoke. But an increase of cloud, and consequent diminution of sunshine, would produce just such a result; and this increase is almost certain to have occurred, owing to the enormously increased amount of dust thrown into the atmosphere as our country has become more densely populated, and especially owing to the vast increase of our smoke-producing manufactories. It seems

highly probable, therefore, that to increase the wealth of our capitalist-manufacturers we are allowing the climate of our whole country to be greatly deteriorated in a way which diminishes both its productiveness and its beauty, thus injuriously affecting the enjoyment and the health of the whole population, since sunshine is itself an essential condition of healthy life. When this fact is thoroughly realized we shall surely put a stop to such a reckless and wholly unnecessary production of injurious smoke and dust.

In conclusion, we find that the much-abused and all-pervading dust, which, when too freely produced, deteriorates our climate and brings us dirt, discomfort, and even disease, is, nevertheless, under natural conditions, an essential portion of the economy of nature. It gives us much of the beauty of natural scenery as due to varying atmospheric effects of sky, and cloud, and sunset tints, and thus renders life more enjoyable; while, as an essential condition of diffused daylight and of moderate rainfalls combined with a dry atmosphere, it appears to be absolutely necessary for our existence upon the earth, perhaps even for the very development of terrestrial, as opposed to aquatic, life. The overwhelming importance of the small things, and even of the despised things, of our world has never, perhaps, been so strikingly brought home to us as in these recent investigations into the widespread and far-reaching beneficial influences of Atmospheric Dust.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The Blue of the Sky and of the Sea

1 What evils are caused through the agency of dust?
2 What should characterize city streets?
3 What blessings come through the agency of dust?

4 What was the old explanation of the color of the sky and of the sea?
5 How does dust affect sunlight?
6 Explain the experiment that proves the effect of dust in the path of a ray of light.
7 Explain the cause of the blue in the sky.
8 Why is the blue of the sky deeper when seen from great elevations?
9 Why are the Italian skies notably blue?
10 Why are the skies of the central Pacific notably blue?
11 Explain the various tints seen in the sky.
12 Explain the cause of the remarkable display of colors at sunset.
13 What is the nature of some volcanic dust?
14 How far is volcanic dust carried?
15 How does volcanic dust affect the sky?
16 What explains the blue of the sea and of deep lakes?
17 Name and explain three sources of minute particles of matter in the sea.
18 What explains the various tints of seas and of lakes?

2 Mist, Clouds, and Rain

19 What does dust do to make the earth habitable?
20 Explain experiments that prove the effects of dust in the atmosphere.
21 Why are we able to see steam?
22 What is the cause of dew?
23 How does dust protect us from the effects of moisture in the air?
24 How does dust prevent deluges of rain?
25 How does dust aid vegetation, and animal life?

3 The Beneficent Effects of Dust

26 Summarize the benefits conferred by dust.
27 What would be the conditions of human life if there were no dust?
28 Explain the colors of the sky at different seasons.
29 Why is rain beneficial to vegetation?
30 How does civilization affect climate?
31 On what does rain depend?
32 What does history show concerning the effects of dust?
33 Why is it necessary to restrict the production of smoke?

34 Explain how the article leads us to appreciate what seems, at first thought, unimportant.

35 What does the last paragraph do to emphasize the thought of the article?

BOOKS FOR FURTHER READING

The Wonderful Century, Alfred Russel Wallace, *Dodd,* 1898.

Studies, Scientific and Social, Alfred Russel Wallace, *Macmillan,* 1900.

Man's Place in the Universe, Alfred Russel Wallace, *Doubleday,* 1905.

My Life, Alfred Russel Wallace, *Dodd,* 1905.

Social Environment and Moral Progress, Alfred Russel Wallace, *Funk,* 1913.

The Adventures of a Grain of Dust, Hallam Hawkesworth, *Scribner,* 1922.

The Strange Adventures of a Pebble, Hallam Hawkesworth, *Scribner,* 1921.

Fire as an Agent in Human Culture, Walter Hough, *Government Printing Office, Washington, D. C.,* 1926.

Some Wonders of Matter, J. E. Mercer, *Macmillan,* 1919.

How the World is Fed, Frank G. Carpenter, *American Book Co.,* 1923.

THE ROMANCE OF THE DIAMOND

By

SIR WILLIAM CROOKES

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"The spectroscope reveals that the elementary components of the stars and the earth are pretty much the same."

SIR WILLIAM CROOKES.

SIR WILLIAM CROOKES
(1832-1919)

The modern theory of electrons owes much to the work of the great English chemist and physicist, Sir William Crookes, whose investigations of the effects of the electric spark in vacuum tubes, or "Crookes tubes," led the way to the new conception. To Sir William Crookes chemistry owes the discovery of the elements, thallium and monium.

Following his studies of diamonds and other precious stones, Sir William Crookes succeeded in making exceedingly small, genuine diamonds. He made various important inventions for the use of scientists, including the radiometer, and did much to lead the people of his time to realize the practical importance of chemistry. In addition, he interested himself in the public welfare, in the fixation of nitrogen for the purpose of increasing the supply of wheat, and in sanitation, in which he became an expert. Because of his great work for science, he was given, at various times, the Royal Medal, the Davy Medal, and the Copley Medal of the Royal Society, was made a Fellow of the Royal Society, and in 1897 was honored with Knighthood.

In 1859, at the age of 27, he founded *The Chemical News,* and for many years he edited *The Quarterly Journal of Science.* He wrote *Select Methods of Chemical Analysis* (1880), and various highly technical works.

THE ROMANCE OF THE DIAMOND

By Sir William Crookes, F.R.S.

I. THE DIAMOND AS A GIFT FROM HEAVEN

FROM the earliest times, the diamond has fascinated mankind. It has been a perennial puzzle—one of the "riddles of the painful earth." Speculations as to the probable origin of the diamond have been greatly forwarded by patient research, and particularly by improved means of obtaining high temperatures, an advance we owe principally to the researches of Professor Moissan.[1]

There is one theory of the origin of diamonds which appeals to the fancy. It is said that the diamond is a gift from Heaven, conveyed to earth in meteoric showers. The suggestion, I believe, was first broached by A. Meydendauer,[2] who said:

"The diamond can only be of cosmic origin, having fallen as a meteorite at later periods of the earth's formation. The available localities of the diamond contain the residues of not very compact meteoric masses, which may, perhaps, have fallen in prehistoric ages, and which have penetrated more or less deeply, according to the more or less resistant character of the surface where they fell. Their remains are crumbling away on exposure to the air and sun, and the rain has long ago washed away all prominent masses. The enclosed diamonds have remained scattered in the river-beds, while the fine, light matrix has been swept away."

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[1] Henri Moissan (1852-1907). A French chemist, winner of the Nobel Prize in Chemistry in 1906, who, by means of the electric furnace, made very small diamonds.

[2] A. Meydendauer. A German mineralogist.

According to this hypothesis, the so-called volcanic pipes peculiar to all diamond-mines are simply holes bored in the solid earth by the impact of monstrous meteors—the larger masses boring the holes, while the smaller masses, disintegrating in their fall, distributed diamonds broadcast.

Bizarre as such a theory appears, I am bound to admit that there are many circumstances which show that the notion of the Heavens raining diamonds is not impossible. The most striking confirmation of the meteoric theory comes from Arizona. Here, on a broad open plain, over an area about five miles in diameter, have been scattered one or two thousand masses of metallic iron, the fragments varying in weight from half a ton to a fraction of an ounce. There is little doubt that these masses formed part of a meteoric shower, although no record exists as to when the fall took place.

Curiously enough, near the centre, where most of the meteorites have been found, is a crater with raised edges three-quarters of a mile in diameter and about six hundred feet deep, bearing exactly the appearance which would be produced had a mighty mass of iron struck the ground and buried itself deep under the surface. Altogether, ten tons of this iron have been collected and specimens of the Cañon Diablo meteorite are in most collectors' cabinets.

An ardent mineralogist, the late Dr. Foote,[3] cutting a section of this meteorite, found the tools were injured by something vastly harder than metallic iron. He examined the specimen chemically, and soon after announced to the scientific world that the Cañon Diablo meteorite contained black and transparent diamonds. This startling discovery was afterwards verified by Professors Moissan and Freidel;[4] and Moissan,

[3] Dr. A. E. Foote. An American mineralogist.
[4] Professor C. Freidel. A French mineralogist.

working on a piece of the Cañon Diablo meteorite, has recently found smooth black diamonds and transparent diamonds, in the form of octahedra with rounded edges, together with green hexagonal crystals of carbon silicide. The presence of carbon silicide in the meteorite shows that it must, at some time, have experienced the temperature of the electric furnace.

Under atmospheric influences the iron would rapidly oxidize and rust away, and the meteoric diamonds would be unaffected and left on the surface of the soil, to be found haphazard when oxidation had removed the last proof of their celestial origin. That there are still lumps of iron left in Arizona is merely due to the extreme dryness of the climate and the comparatively short time the iron has been on our planet. We are witnesses to the course of an event which may have happened in geologic times anywhere on the earth's surface.

Although in Arizona diamonds have fallen from the skies, confounding our senses, this descent of precious stones is what may be called a freak of nature rather than a normal occurrence. To the average reader it is now known that there is no great difference between the composition of our earth and that of extraterrestrial masses. The mineral peridot is present in most meteorites. Yet no one doubts that peridot is also a true constituent of rocks formed on this earth. The spectroscope reveals that the elementary components of the stars and the earth are pretty much the same. The spectroscope also shows that meteorites have as much of earth as of heaven in their composition. Indeed, not only are the selfsame elements present in meteorites, but they are combined in the same way to form the same minerals as in the crust of the earth.

It is certain from observations I have made, corroborated by experience gained in the laboratory, that iron at a high temperature and under great pressure—conditions existent at great

depths below the surface of the earth—acts as the long-sought solvent for carbon, and will allow it to crystallize out in the form of diamond. But it is also certain, from the evidence afforded by the Arizona and other meteorites, that similar conditions have existed among bodies in space, and that on more than one occasion a meteorite freighted with jewels has fallen as a star from the sky.

2. THE ORIGIN OF THE DIAMOND

Many circumstances point to the conclusion that the diamond of the chemist and the diamond of the mine are strangely akin as to origin. It is evident that the diamond has not been formed *in situ*[5] in the blue ground[6] where it is found. The genesis must have taken place at vast depths under enormous pressure. The explosion of large diamonds on coming to the surface shows extreme tension. More diamonds are found in fragments and splinters than in perfect crystals; and it is noteworthy that, although these splinters and fragments must be derived from the breaking up of a large crystal, yet in only one instance have pieces been found which could be fitted together; and these occurred at different levels. Does not this fact point to the conclusion that the blue ground is not their true matrix? Nature does not make fragments of crystals. As the edges of the crystals are still sharp and unabraded, the *locus*[7] of formation cannot have been very distant from the present sites. There were probably many sites of crystallization differing in place and time, or we should not see such distinctive characters in the gems from different mines, nor indeed in diamonds from different parts of the same mine.

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[5] In situ. In its original position.
[6] Blue ground. The hard, blue-green rock in which diamonds are found.
[7] Locus. Place.

Although my experiments are chiefly connected with the physical and chemical properties of diamonds, and with researches on the perplexities of their probable formation, it will be a kind of compensation for some of my theories if I bring before the reader the general character of the South-African diamond-mines and their surroundings.

3. THE DIAMOND MINES AT KIMBERLEY

The most famous diamond-mines in the world are Kimberley, DeBeers, Dutoitspan, Bulfontein and Wesselton. Kimberley[8] is practically in the center of the present diamond-producing area. The five diamond-mines are all contained in a precious circle three and one-half miles in diameter. They are irregular-shaped round or oval pipes, extending vertically downwards to unknown depths, and becoming narrower as the depth increases. They are considered to be volcanic necks filled from below with a heterogeneous mixture of fragments of surrounding rocks, and of older rocks, such as granite, mingled and cemented with a bluish-colored hard mass, in which famous "blue ground" the imbedded diamonds are hidden.

How the great pipes were originally formed it is hard to say. They were certainly not burst through in the ordinary manner of volcanic eruptions, since the surrounding and enclosing walls show no signs of igneous action, and are not shattered or broken up even when touching the "blue ground." It is pretty certain that these pipes were filled from below after they were pierced, and the diamonds were formed at some previous time

[8] Kimberley. The city of Kimberley, South Africa, was founded in 1870, when diamonds were found on farm land in that place. The various mines known as the Kimberley, DeBeers, Dutoitspan, Bulfontein, and Wesselton, all belong to the DeBeers Company. The various mines produced diamonds of varying qualities. Some of the mines are now closed.

and mixed with a mud volcano, together with all kinds of débris eroded from the rocks through which it erupted, forming a geological "plum pudding." A more wildly heterogeneous mixture can hardly be found anywhere else on this globe.

It may be that each volcanic pipe is the vent for its own laboratory—a laboratory buried at vastly greater depths than we have yet reached—where the temperature is comparable with that of the electric furnace, where the pressure is fiercer than in our puny laboratories and the melting-point higher, where no oxygen is present, and where masses of liquid carbon have taken centuries, perhaps thousands of years, to cool to the solidifying-point.

In 1903 the Kimberley mine had reached a depth of 2,599 feet. Tunnels are driven from the various shafts at different levels, about 120 feet apart, to cross the mine from west to east. These tunnels are connected by two other tunnels running north and south. The scene belowground in the labyrinth of galleries is bewildering in its complexity, and very unlike the popular notion of a diamond-mine. All below is dirt, mud, grime; half-naked men dark as mahogany, lithe as athletes, dripping with perspiration, are seen in every direction, hammering, picking, shoveling, wheeling the trucks to and fro, keeping up a weird chant which rises in force and rhythm when a greater task calls for excessive muscular strain. The whole scene is more suggestive of a coal-mine than of a diamond-mine, and all this mighty organization—this strenuous expenditure of energy, this costly machinery, this ceaseless toil of skilled and black labor—goes on day and night, just to win a few stones wherewith to deck my lady's finger! All to gratify the vanity of woman! "And," I hear my fair reader remark, "the depravity of man!"

Prodigious diamonds[9] are not so uncommon as is generally supposed. Diamonds weighing over an ounce (151.5 carats) are not unfrequent at Kimberley. I have seen in one parcel of stones eight perfect ounce crystals, and one inestimable stone weighing two ounces. The largest known diamond, the "Cullinan," was found in the New Premier Mine. It weighs no less than 3,025 carats, or 1.37 pounds avoirdupois. It is a fragment, probably less than half, of a distorted octahedral crystal. The other portions still await discovery by some fortunate miner.

At the close of the year 1904, ten tons of diamonds had come from these mines, valued at $300,000,000. This mass of blazing gems could be accommodated in a box five feet square and six feet high. The diamond has a peculiar luster, and on the sorter's table it is impossible to mistake it for any other stone. It looks somewhat like clear gum arabic. From the sorting-room the stones are taken to the Diamond Office to be cleaned in acids and sorted into classes by the valuators, according to color and purity. It is a sight for Aladdin[10] to behold the sorters at work. In the Kimberley treasure store the tables are literally heaped with stones won from the rough blue ground —stones of all sizes, purified, flashing and of inestimable price; stones coveted by men and women all the world over.

Where fabulous riches are concentrated into so small a bulk, it is not surprising that precautions against robbery are elaborate. The Illicit Diamond-Buying Laws[11] are very stringent;

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[9] Prodigious diamonds. In 1896 a diamond weighing 503 carats was found in the DeBeers mine; in 1917 a diamond weighing 442 carats was found in Dutoitspan.

[10] Aladdin. According to *The Arabian Nights Entertainment* Aladdin, a poor man, through control of a magic lamp and a magic ring, was able to command the possession of vast treasures.

[11] Illicit Diamond-Buying Laws. In the neighborhood of the diamond mines the stealing of diamonds reached such proportions that strict laws were passed governing the finding, possession, and sale of diamonds.

and the searching, rendered easy by the "compounding" of the natives, is of the most drastic character. The value of stolen diamonds at one time reached nearly $5,000,000 a year. Now the safeguard against this is the "compound." This is a large square, about twenty acres, surrounded by rows of one-story buildings, divided into rooms holding about twenty natives each.

Within the enclosure is a store where the necessaries of life are supplied at a reduced price, and wood and water free. In the middle is a large swimming-bath with fresh water running through it. The rest of the space is devoted to games, dances, concerts, and any other amusement the native mind can desire. In the compound are to be seen representatives of nearly all the picked types of African tribes. The clothing in the compound is diverse and original. Some of the men are evident dandies, whilst others think that in so hot a climate a bright-colored handkerchief or "a pair of spectacles and a smile" is as great a compliance with the requirements of civilization as can be expected.

One Sunday afternoon, my wife and I walked unattended about the compound, almost the only whites present among 1,700 natives. At one part a Kaffir [12] was making a pair of trousers with a bright nickel-plated sewing-machine, in which he had invested his savings. Next to him, a "boy" was reading from the Testament in his own language to an attentive audience. In a corner, a party were engaged in cooking a savory mess in an iron pot; and, farther on, the orchestra was tuning up, and Zulus [13] were putting the finishing-touches to their toilet of feathers and beads. One group was intently watching

[12] Kaffir. A name applied generally to natives of Africa south of the equator, but often restricted to certain tribes.

[13] Zulus. Members of a warlike, native race in southeastern Africa.

a mysterious game. It is played by two sides, with stones and grooves and hollows in the ground, and appears to be of most absorbing interest. It seems to be universal throughout Africa; it is met with among the ruins of Zimbabwe,[14] and signs of it are recorded on old Egyptian monuments.

4. CHARACTERISTICS OF DIAMONDS

A word as to the hardness of diamonds. They vary much in this respect; even different parts of the same crystal differ in their resistance to cutting and grinding. So hard is diamond in comparison to glass that a suitable splinter of diamond will plane curls off a glass plate as a carpenter's tool will plane shavings off a deal board. Another experiment that will illustrate its hardness is to place a diamond on the flattened end of a conical block of steel, and upon it bring another similar cone of steel. If I force them together with hydraulic power I can force the stone into the steel blocks without injuring the diamond in the least. The pressure which I have brought to bear in this experiment has been equal to 170 tons per square inch of diamond.

The only serious rival of the diamond in hardness is the metal tantalum. In an attempt to bore a hole through a plate of this metal, a diamond drill was used revolving at the rate of 5,000 revolutions per minute. This whirling force was continued ceaselessly for three days and nights, when it was found that only a small point, one-fourth of a millimeter deep, had been drilled, and it was a moot point which had suffered more damage, the diamond or the tantalum.

After exposure for some time to the sun, many diamonds glow in a dark room. One beautiful green diamond in my collection, when phosphorescing in a vacuum, gives almost as

[14] Zimbabwe. An ancient ruined city in southeastern Africa.

much light as a candle, and you can easily read by its rays. But the time has hardly come when we can use diamonds as domestic illuminants! Mrs. Kunz, wife of the well-known New York mineralogist,[15] possesses perhaps the most remarkable of all phosphorescing diamonds. This prodigy diamond will phosphoresce in the dark for some minutes after being exposed to a small pocket electric light, and if rubbed on a piece of cloth a long streak of phosphorescence appears.

5. THE MANUFACTURE OF DIAMONDS

For the manufacture of a diamond, the first necessity is to select pure iron—free from sulphur, silicon, phosphorus, and so forth—and to pack it in a carbon crucible with pure charcoal from sugar. The crucible is then put into the body of the electric furnace, and a powerful arc formed close above it between carbon poles, utilizing a current of 700 amperes at 40 volts pressure. The iron rapidly melts and saturates itself with carbon. After a few minutes' heating to a temperature above 4,000° C.—a temperature at which the iron melts like wax and volatilizes in clouds—the current is stopped, and the dazzling fiery crucible is plunged beneath the surface of cold water, where it is held till it sinks below a red heat.

As is well known, iron increases in volume at the moment of passing from the liquid to the solid state. The sudden cooling solidifies the outer layer of iron and holds the inner molten mass in a tight grip. The expansion of the inner liquid on solidifying produces an enormous pressure, and under the stress of this pressure the dissolved carbon separates out in transparent forms—minutely microscopic, it is true—but all the same veritable diamonds, with crystalline form and appear-

[15] George F. Kunz (1856-). An American mineralogist, expert in gems.

ance, color, hardness and action on light the same as the natural gem.

Now commences the tedious part of the process. The metallic ingot is attacked with hot nitro-hydrochloric acid until no more iron is dissolved. The bulky residue consists chiefly of graphite, together with translucent chestnut-colored flakes of carbon, black opaque carbon as hard as diamonds—black diamonds, in fact—and a small portion of transparent colorless diamonds showing crystalline structure.

The residue is first heated for some hours with strong sulphuric acid at the boiling-point, with the cautious addition of powdered niter. It is then well washed, and for two days allowed to soak in strong hydrofluoric acid in cold, then in boiling, acid. After this treatment the soft graphite disappears, and most, if not all, the silicon compounds have been destroyed.

Hot sulphuric acid is again applied to destroy the fluorides; and the residue, well washed, is attacked with a mixture of the strongest nitric acid and powdered potassium chlorate, kept warm—but not above 60° C., to avoid explosions. This treatment must be repeated six or eight times, when all the hard graphite will gradually be dissolved, and little else left but graphitic oxide, diamond and the harder carbonado or black diamond and boart.[16] The residue is fused for an hour in fluorhydrate of fluoride of potassium, then boiled out in water, and again heated in sulphuric acid.

The well-washed grains which resist this energetic treatment are dried, carefully deposited on a slide and examined under the microscope. Although many fragments of crystals occur, it is remarkable I have never seen a complete crystal. All appear shattered, as if on being liberated from the intense pressure under which they were formed they burst asunder. I have

[16] Boart. Impure diamond used for cutting and polishing.

singular evidence of this phenomenon. A fine piece of artificial diamond, carefully mounted by me on a microscopic slide, exploded during the night and covered the slide with fragments. This bursting paroxysm is not unknown at the Kimberley diamond mines.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The Diamond as a Gift from Heaven

1 Why were diamonds thought to be "gifts from heaven"?
2 Describe Cañon Diablo.
3 In what respects is the Cañon Diablo meteorite remarkable?
4 How do we know the composition of the stars?

2 The Origin of the Diamond

5 How may diamonds have been formed?
6 Why do diamond miners find many broken crystals?

3 The Diamond Mines at Kimberley

7 In what peculiar surroundings are diamonds found?
8 Explain the theory concerning volcanic pipes at Kimberley.
9 What theory accounts for the formation of diamonds?
10 Describe a diamond mine.
11 Tell the characteristics of some of the largest diamonds.
12 What is the process of diamond mining?
13 Describe the compound at Kimberley.
14 What kind of men work in the diamond mines at Kimberley?

4 Characteristics of the Diamond

15 How hard is the diamond?
16 How hard is tantalum?
17 Tell about the phosphorescence of the diamond.

5 The Manufacture of Diamonds

18 How is it possible to manufacture diamonds?
19 Why is the article called a "romance"?
20 Summarize the most interesting facts concerning the diamond.

BOOKS FOR FURTHER READING

Diamonds, Frank B. Wade, *Putnam,* 1916.
A Textbook of Precious Stones, Frank B. Wade, *Putnam,* 1918.
Gold, Its Place in the Economy of Mankind, Benjamin White, *Pitman,* 1920.
Silver, Its Intimate Association with the Daily Life of Man, Benjamin White, *Pitman,* 1920.
The Story of Iron, Elizabeth I. Samuel, *Penn,* 1917.
Copper, From the Ore to the Metal, H. K. Packard, *Pitman,* 1916.
Asbestos, the World's Most Wonderful Mineral, A. L. Summers, *Pitman,* 1929.
The World's Minerals, Leonard S. Spencer, *Stokes,* 1916.

NIAGARA

By

JOHN TYNDALL

Reprinted from FRAGMENTS OF SCIENCE, *by John Tyndall.*

"Time and intensity are the main factors in geologic change, and they are in a certain sense convertible. A feeble force acting through long periods, and an intense force acting through short ones, may produce approximately the same results."

JOHN TYNDALL.

JOHN TYNDALL
(1820-1893)

John Tyndall is interesting for stalwart manhood, and for invaluable work for science.

Born in a humble home in Ireland, not surrounded in early life by apparent opportunities, he rose from poverty to the position of leading scientist. He became a bold Alpine climber, and in 1861 was the first to ascend the Weisshorn; in 1868 he climbed the Matterhorn. As a lecturer Professor Tyndall had the power to speak simply and clearly on difficult subjects. When he earned thousands of dollars by lectures in America in 1872 and 1873 he gave the entire sum for the advancement of scientific investigations.

Professor Tyndall did more than almost anyone else to interest the people of his day in science, and to introduce science to ordinary people.

Professor Tyndall made important studies of magnetism, heat, sound, light, and glacier motion, and in general devoted himself to physical studies. He became Fellow of the Royal Society, Professor of Natural Philosophy at the Royal Institute, and, in 1867, Superintendent of the Royal Institute.

Some of his books are: *Heat as a Mode of Motion* (1863); *On Sound* (1867); *Faraday as a Discoverer* (1868); *Diamagnetism and Magnecrystallic Action* (1870); *The Imagination in Science* (1870); *Fragments of Science for Unscientific People* (1871); *Hours of Exercise in the Alps* (1871); *Contributions to Molecular Physics in the Domain of Radiant Heat* (1872); *The Forms of Water* (1872); *Lectures on Light* (1873); *On the Transmission of Sound by the Atmosphere* (1874); *Lessons in Electricity* (1876); *Fermentation* (1877); *Floating Matter in the Air in Relation to Putrefaction and Infection* (1881); *Free Molecules and Radiant Heat* (1882); *New Fragments of Science* (1892).

The essay on *Niagara* is from *Fragments of Science,* one of the volumes in which Professor Tyndall brought together various essays, addresses, and reviews.

NIAGARA

By John Tyndall

I. EARLY EXAGGERATIONS ABOUT NIAGARA

IT IS one of the disadvantages of reading books about natural scenery that they fill the mind with pictures, often exaggerated, often distorted, often blurred, and, even when well drawn, injurious to the freshness of first impressions. Such has been the fate of most of us with regard to the Falls of Niagara. There was little accuracy in the estimates of the first observers of the cataract. Startled by an exhibition of power so novel and so grand, emotion leaped beyond the control of the judgment, and gave currency to notions which have often led to disappointment.

A record of a voyage in 1535 by a French mariner named Jacques Cartier,[1] contains, it is said, the first printed allusion to Niagara. In 1603 the first map of the district was constructed by a Frenchman named Champlain.[2] In 1648 the Jesuit Ragenau,[3] in a letter to his superior at Paris, mentions Niagara as a "cataract of frightful height." In the winter of 1678 and 1679 the cataract was visited by Father Hennepin,[4] and described in a book dedicated "To the King of Great Britain." He gives a drawing of the waterfall, which shows that serious changes have taken place since his time. He describes it as

[1] Jacques Cartier (1494-1552?). A French explorer of Canada.

[2] Samuel de Champlain (1567-1635). A French explorer of Canada.

[3] Paul Ragenau (1608-1680). A French missionary and explorer in Canada.

[4] Louis Hennepin (1640-1701?). A French missionary and explorer of Canada.

"a great and prodigious cadence of water, to which the universe does not offer a parallel." The height of the fall, according to Hennepin, was more than 600 feet. "The waters," he says, "which fall from this great precipice do foam and boil in the most astonishing manner, making a noise more terrible than that of thunder. When the wind blows to the south its frightful roaring may be heard for more than fifteen leagues." The Baron la Hontan,[5] who visited Niagara in 1687, makes the height 800 feet. In 1721 Charlevois,[6] in a letter to Madame de Maintenon,[7] after referring to the exaggerations of his predecessors, thus states the result of his own observations: "For my part, after examining it on all sides, I am inclined to think that we cannot allow it less than 140 or 150 feet,"—a remarkably close estimate. At that time, viz. a hundred and fifty years ago, it had the shape of a horseshoe, and reasons will subsequently be given for holding that this has been always the form of the cataract, from its origin to its present site.

As regards the noise of the fall, Charlevois declares the accounts of his predecessors, which, I may say, are repeated to the present hour, to be altogether extravagant. He is perfectly right. The thunders of Niagara are formidable enough to those who really seek them at the base of the Horseshoe Fall; but on the banks of the river, and particularly above the fall, its silence, rather than its noise, is surprising. This arises, in part, from the lack of resonance; the surrounding country being flat, and therefore furnishing no echoing surfaces to reinforce the shock of the water. The resonance from the

[5] Baron Armand de la Hontan (1667-1715). A French military leader who served in America.

[6] Pierre de Charlevois (1682-1761). A French missionary and explorer of Canada.

[7] Madame de Maintenon. (1635-1719.) Françoise d'Aubigné, Marquise de Maintenon, the second wife of Louis XIV, King of France.

surrounding rocks causes the Swiss Reuss[8] at the Devil's Bridge, when full, to thunder more loudly than the Niagara.

2. FIRST GENERAL IMPRESSIONS OF NIAGARA

On Friday, November 1, 1872, just before reaching the village of Niagara Falls, I caught, from the railway train, my first glimpse of the smoke of the cataract. Immediately after my arrival I went with a friend to the northern end of the American Fall. It may be that my mood at the time toned down the impression produced by the first aspect of this grand cascade; but I felt nothing like disappointment, knowing, from old experience, that time and close acquaintanceship, the gradual interweaving of mind and nature, must powerfully influence my final estimate of the scene. After dinner we crossed to Goat Island, and, turning to the right, reached the southern end of the American Fall. The river is here studded with small islands. Crossing a wooden bridge to Luna Island, and clasping a tree which grows near its edge, I looked long at the cataract, which here shoots down the precipice like an avalanche of foam. It grew in power and beauty. The channel spanned by the wooden bridge was deep, and the river there doubled over the edge of the precipice, like the swell of a muscle, unbroken. The ledge here overhangs, the water being poured out far beyond the base of the precipice. A space, called the Cave of the Winds, is thus enclosed between the wall of rock and the falling water.

Goat Island ends in a sheer dry precipice, which connects the American and Horseshoe Falls. Midway between both is a wooden hut, the residence of the guide to the Cave of the Winds, and from the hut a winding staircase, called Biddle's Stairs, descends to the base of the precipice. On the evening

[8] Reuss. A river in Switzerland, 90 miles long.

of my arrival I went down this stair, and wandered along the bottom of the cliff. One well-known factor in the formation and retreat of the cataract was immediately observed. A thick layer of limestone formed the upper portion of the cliff. This rested upon a bed of soft shale, which extended round the base of the cataract. The violent recoil of the water against this yielding substance crumbles it away, undermining the ledge above, which, unsupported, eventually breaks off, and produces the observed recession.

At the southern extremity of the Horseshoe is a promontory, formed by the doubling back of the gorge excavated by the cataract, and into which it plunges. On the promontory stands a stone building, called the Terrapin Tower, the door of which had been nailed up because of the decay of the staircase within it. Through the kindness of Mr. Townsend, the superintendent of Goat Island, the door was opened for me. From this tower, at all hours of the day, and at some hours of the night, I watched and listened to the Horseshoe Fall. The river here is evidently much deeper than the American branch; and instead of bursting into foam where it quits the ledge, it bends solidly over, and falls in a continuous layer of the most vivid green. The tint is not uniform; long stripes of deeper hue alternating with bands of brighter color. Close to the ledge over which the water rolls, foam is generated, the light falling upon which, and flashing back from it, is sifted in its passage to and fro, and changed from white to emerald-green. Heaps of superficial foam are also formed at intervals along the ledge, and are immediately drawn into long white striæ. Lower down, the surface, shaken by the reaction from below, incessantly rustles into whiteness. The descent finally resolves itself into a rhythm, the water reaching the bottom of the fall in periodic gushes. Nor is the spray uniformly diffused through

the air, but is wafted through it in successive veils of gauze-like texture. From all this it is evident that beauty is not absent from the Horseshoe Fall, but majesty is its chief attribute. The plunge of the water is not wild, but deliberate, vast, and fascinating. From the Terrapin Tower, the adjacent arm of the Horseshoe is seen projected against the opposite one, midway down; to the imagination, therefore, is left the picturing of the gulf into which the cataract plunges.

The delight which natural scenery produces in some minds is difficult to explain, and the conduct which it prompts can hardly be fairly criticised by those who have never experienced it. It seems to me a deduction from the completeness of the celebrated Thomas Young,[9] that he was unable to appreciate natural scenery. "He had really," says Dean Peacock,[10] "no taste for life in the country; he was one of those who thought that no one who was able to live in London would be content to live elsewhere." Well, Dr. Young, like Dr. Johnson,[11] had a right to his delights; but I can understand a hesitation to accept them, high as they were, to the exclusion of

> That o'erflowing joy which Nature yields
> To her true lovers.

To all who are of this mind, the strengthening of desire on my part to see and know Niagara Falls, as far as it is possible for them to be seen and known, will be intelligible.

3. UNDER THE WATERFALL

On the first evening of my visit, I met, at the head of Biddle's Stair, the guide to the Cave of the Winds. He was in the

[9] Thomas Young (1773-1829). An English physicist.

[10] George Peacock (1791-1858). Dean of Ely, England. An English mathematician and astronomer.

[11] Samuel Johnson (1709-1784). A great English essayist, poet, and literary leader.

prime of manhood—large, well built, firm and pleasant in mouth and eye. My interest in the scene stirred up his, and made him communicative. Turning to a photograph, he described, by reference to it, a feat which he had accomplished some time previously, and which had brought him almost under the green water of the Horseshoe Fall. "Can you lead me there to-morrow?" I asked. He eyed me enquiringly, weighing, perhaps, the chances of a man of light build, and with grey in his whiskers, in such an undertaking. "I wish," I added, "to see as much of the fall as can be seen, and where you lead I will endeavor to follow." His scrutiny relaxed into a smile, and he said, "Very well; I shall be ready for you to-morrow."

On the morrow, accordingly, I came. In the hut at the head of Biddle's Stair I stripped wholly, and re-dressed according to instructions,—drawing on two pairs of woollen pantaloons, three woollen jackets, two pairs of socks, and a pair of felt shoes. Even if wet, my guide assured me that the clothes would keep me from being chilled; and he was right. A suit and hood of yellow oilcloth covered all. Most laudable precautions were taken by the young assistant who helped to dress me to keep the water out; but his devices broke down immediately when severely tested.

We descended the stair; the handle of a pitchfork doing, in my case, the duty of an alpenstock. At the bottom, the guide enquired whether we should go first to the Cave of the Winds, or to the Horseshoe, remarking that the latter would try us most. I decided on getting the roughest done first, and he turned to the left over the stones. They were sharp and trying. The base of the first portion of the cataract is covered with huge boulders, obviously the ruins of the limestone ledge above. The water does not distribute itself uniformly among

these, but seeks out channels through which it pours torrentially. We passed some of these with wetted feet, but without difficulty. At length we came to the side to a more formidable current. My guide walked along its edge until he reached its least turbulent portion. Halting, he said, "This is our greatest difficulty; if we can cross here, we shall get far towards the Horseshoe."

He waded in. It evidently required all his strength to steady him. The water rose above his loins, and it foamed still higher. He had to search for footing, amid unseen boulders, against which the torrent rose violently. He struggled and swayed, but he struggled successfully, and finally reached the shallower water at the other side. Stretching out his arm, he said to me, "Now come on." I looked down the torrent, as it rushed to the river below, which was seething with the tumult of the cataract. De Saussure [12] recommended the inspection of Alpine dangers, with the view of making them familiar to the eye before they are encountered; and it is a wholesome custom in places of difficulty to put the possibility of an accident clearly before the mind, and to decide beforehand what ought to be done should the accident occur. Thus wound up in the present instance, I entered the water. Even where it was not more than knee-deep, its power was manifest. As it rose around me, I sought to split the torrent by presenting a side to it; but the insecurity of the footing enabled it to grasp my loins, twist me fairly round, and bring its impetus to bear upon my back. Further struggle was impossible; and feeling my balance hopelessly gone, I turned, flung myself toward the bank just quitted, and was instantly, as expected, swept into shallower water.

The oilcloth covering was a great incumbrance; it had been made for a much stouter man, and, standing upright after

[12] Horace De Saussure (1740-1799). A Swiss physicist and geologist.

my submersion, my legs occupied the centre of two bags of water. My guide exhorted me to try again. Prudence was at my elbow, whispering dissuasion; but, taking everything into account, it appeared more immoral to retreat than to proceed. Instructed by the first misadventure, I once more entered the stream. Had the alpenstock been of iron it might have helped me; but, as it was, the tendency of the water to sweep it out of my hands rendered it worse than useless. I, however, clung to it by habit. Again the torrent rose, and again I wavered; but, by keeping the left hip well against it, I remained upright, and at length grasped the hand of my leader at the other side. He laughed pleasantly. The first victory was gained, and he enjoyed it. "No traveller," he said, "was ever here before." Soon afterwards, by trusting to a piece of drift-wood which seemed firm, I was again taken off my feet, but was immediately caught by a protruding rock.

We clambered over the boulders towards the thickest spray, which soon became so weighty as to cause us to stagger under its shock. For the most part nothing could be seen; we were in the midst of bewildering tumult, lashed by the water, which sounded at times like the cracking of innumerable whips. Underneath this was the deep resonant roar of the cataract. I tried to shield my eyes with my hands, and look upwards; but the defence was useless. The guide continued to move on, but at a certain place he halted, desiring me to take shelter in his lee, and observe the cataract. The spray did not come so much from the upper ledge, as from the rebound of the shattered water when it struck the bottom. Hence the eyes could be protected from the blinding shock of the spray, while the line of vision to the upper ledges remained to some extent clear. On looking upwards over the guide's shoulder I could see the water bending over the ledge, while the Terrapin Tower

loomed fitfully through the intermittent spray-gusts. We were right under the tower. A little farther on the cataract, after its first plunge, hit a protuberance some way down, and flew from it in a prodigious burst of spray; through this we staggered. We rounded the promontory on which the Terrapin Tower stands, and moved, amid the wildest commotion, along the arm of the Horseshoe, until the boulders failed us, and the cataract fell into the profound gorge of the Niagara River.

Here the guide sheltered me again, and desired me to look up; I did so, and could see, as before, the green gleam of the mighty curve sweeping over the upper ledge, and the fitful plunge of the water, as the spray between us and it alternately gathered and disappeared. An eminent friend of mine often speaks of the mistake of those physicians who regard man's ailments as purely chemical, to be met by chemical remedies only. He contends for the psychological element of cure. By agreeable emotions, he says, nervous currents are liberated which stimulate blood, brain, and viscera. The influence rained from ladies' eyes enables my friend to thrive on dishes which would kill him if eaten alone. A sanative effect of the same order I experienced amid the spray and thunder of Niagara. Quickened by the emotions there aroused, the blood sped exultingly through the arteries, abolishing introspection, clearing the heart of all bitterness, and enabling one to think with tolerance, if not with tenderness, on the most relentless and unreasonable foe. Apart from its scientific value, and purely as a moral agent, the play was worth the candle. My companion knew no more of me than that I enjoyed the wildness of the scene; but as I bent in the shelter of his large frame he said, "I should like to see you attempting to describe all this." He rightly thought it indescribable. The name of this gallant fellow was Thomas Conroy.

We returned, clambering at intervals up and down, so as to catch glimpses of the most impressive portions of the cataract. We passed under ledges formed by tabular masses of limestone, and through some curious openings formed by the falling together of the summits of the rocks. At length we found ourselves beside our enemy of the morning. Conroy halted for a minute or two, scanning the torrent thoughtfully. I said that, as a guide, he ought to have a rope in such a place; but he retorted that, as no traveller had ever thought of coming there, he did not see the necessity of keeping a rope. He waded in. The struggle to keep himself erect was evident enough; he swayed, but recovered himself again and again. At length he slipped, gave way, did as I had done, threw himself towards the bank, and was swept into the shallows. Standing in the stream near its edge, he stretched his arm towards me. I retained the pitchfork handle, for it had been useful among the boulders. By wading some way in, the staff could be made to reach him, and I proposed his seizing it. "If you are sure," he replied, "that, in case of giving way, you can maintain your grasp, then I will certainly hold you." Remarking that he might count on this, I waded in, and stretched the staff to my companion. It was firmly grasped by both of us. Thus helped, though its onset was strong, I moved safely across the torrent. All danger ended here. We afterwards roamed sociably among the torrents and boulders below the Cave of the Winds. The rocks were covered with organic slime, which could not have been walked over with bare feet, but the felt shoes effectually prevented slipping. We reached the cave and entered it, first by a wooden way carried over the boulders, and then along a narrow ledge, to the point eaten deepest in the shale. When the wind is from the south, the falling water, I am told, can be seen tranquilly from this spot; but when we

were there, a blinding hurricane of spray was whirled against us. On the evening of the same day, I went behind the water on the Canada side, which, after the experiences of the morning, struck me as an imposture.

Still even this latter is exciting to some nerves. Its effect upon himself is thus vividly described by Mr. Bakewell, jun.:[13] "On turning a sharp angle of the rock, a sudden gust of wind met us, coming from the hollow between the fall and the rock, which drove the spray directly in our faces, with such force that in an instant we were wet through. When in the midst of this shower-bath the shock took away my breath: I turned back and scrambled over the loose stones to escape the conflict. The guide soon followed, and told me that I had passed the worst part. With that assurance I made a second attempt; but so wild and disordered was my imagination that when I had reached half way I could bear it no longer."

4. VIEWS OF NIAGARA FROM THE RIVER BELOW THE FALLS

To complete my knowledge I desired to see the fall from the river below it, and long negotiations were necessary to secure the means of doing so. The only boat fit for the undertaking had been laid up for the winter; but this difficulty, through the kind intervention of Mr. Townsend, was overcome. The main one was to secure oarsmen sufficiently strong and skilful to urge the boat where I wished it to be taken. The son of the owner of the boat, a finely-built young fellow, but only twenty, and therefore not sufficiently hardened, was willing to go; and up the river, it was stated, there lived another man who could do anything with the boat which strength and daring could accomplish. He came. His figure and expression of face certainly indicated extraordinary firmness and power.

[13] Robert Bakewell, Jr. (1768-1843). An English geologist.

On Tuesday, November 5, we started, each of us being clad in oilcloth. The elder oarsman at once assumed a tone of authority over his companion, and struck immediately in amid the breakers below the American Fall. He hugged the cross freshets instead of striking out into the smoother water. I asked him why he did so, and he replied that they were directed outwards, not downwards. The struggle, however, to prevent the bow of the boat from being turned by them, was often very severe.

The spray was in general blinding, but at times it disappeared and yielded noble views of the fall. The edge of the cataract is crimped by indentations which exalt its beauty. Here and there, a little below the highest ledge, a secondary one juts out; the water strikes it and bursts from it in huge protuberant masses of foam and spray. We passed Goat Island, came to the Horseshoe, and worked for a time along its base, the boulders over which Conroy and myself had scrambled a few days previously lying between us and the cataract. A rock was before us, concealed and revealed at intervals, as the waves passed over it. Our leader tried to get above this rock, first on the outside of it. The water, however, was here in violent motion. The men struggled fiercely, the older one ringing out an incessant peal of command and exhortation to the younger. As we were just clearing the rock, the bow came obliquely to the surge; the boat was turned suddenly round and shot with astonishing rapidity down the river. The men returned to the charge, now trying to get up between the half-concealed rock and the boulders to the left. But the torrent set in strongly through this channel. The tugging was quick and violent, but we made little way. At length, seizing a rope, the principal oarsman made a desperate attempt to get upon one of the boulders, hoping to be able to drag the boat through the chan-

nel; but it bumped so violently against the rock, that the man flung himself back and relinquished the attempt.

We returned along the base of the American Fall, running in and out among the currents which rushed from it laterally into the river. Seen from below the American Fall is certainly exquisitely beautiful, but it is a mere frill of adornment to its nobler neighbor, the Horseshoe. At times we took to the river, from the center of which the Horseshoe Fall appeared especially magnificent. A streak of cloud across the neck of Mont Blanc [14] can double its apparent height, so here the green summit of the cataract shining above the smoke of spray appeared lifted to an extraordinary elevation. Had Hennepin [15] and La Hontan [16] seen the fall from this position, their estimates of the height would have been perfectly excusable.

5. THE WHIRLPOOL RAPIDS

From a point a little way below the American Fall, a ferry crosses the river, in summer, to the Canadian side. Below the ferry is a suspension bridge for carriages and foot-passengers, and a mile or two lower down is the railway suspension bridge. Between ferry and bridge the river Niagara flows unruffled; but at the suspension bridge the bed steepens and the river quickens its motion. Lower down the gorge narrows, and the rapidity and turbulence increase. At the place called the "Whirlpool Rapids" I estimated the width of the river at 300 feet, an estimate confirmed by the dwellers on the spot. When it is remembered that the drainage of nearly half a continent is compressed into this space, the impetuosity of the river's rush may

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[14] Mont Blanc. The highest mountain of the Alps. Its altitude is 15,781 feet.

[15] See note 4.

[16] See note 5.

be imagined. Had it not been for Mr. Bierstädt,[17] the distinguished photographer of Niagara, I should have quitted the place without seeing these rapids; for this, and for his agreeable company to the spot, I have to thank him. From the edge of the cliff above the rapids, we descended, a little, I confess, to a climber's disgust, in an "elevator," because the effects are best seen from the water level.

Two kinds of motion are here obviously active, a motion of translation and a motion of undulation—the race of the river through its gorge, and the great waves generated by its collision with, and rebound from, the obstacles in its way. In the middle of the river the rush and tossing are most violent; at all events, the impetuous force of the individual waves is here most strikingly displayed. Vast pyramidal heaps leap incessantly from the river, some of them with such energy as to jerk their summits into the air, where they hang momentarily suspended in crowds of liquid spherules. The sun shone for a few minutes. At times the wind, coming up the river, searched and sifted the spray, carrying away the lighter drops, and leaving the heavier ones behind. Wafted in the proper direction, rainbows appeared and disappeared fitfully in the lighter mist. In other directions the common gleam of the sunshine from the waves and their shattered crests was exquisitely beautiful. The complexity of the action was still further illustrated by the fact, that in some cases, as if by the exercise of a local explosive force, the drops were shot radially from a particular center, forming around it a kind of halo.

The first impression, and, indeed, the current explanation of these rapids is, that the central bed of the river is cumbered with large boulders, and that the jostling, tossing, and wild

[17] Edward Bierstädt. In 1860 maker of a remarkable picture of Niagara Falls from Goat Island.

leaping of the water there, are due to its impact against these obstacles. I doubt this explanation. At all events, there is another sufficient reason to be taken into account. Boulders derived from the adjacent cliffs visibly cumber the sides of the river. Against these the water rises and sinks rhythmically but violently, large waves being thus produced. On the generation of each wave, there is an immediate compounding of the wave-motion with the river-motion. The ridges, which in still water would proceed in circular curves round the center of disturbance, cross the river obliquely, and the result is that at the centre waves commingle, which have really been generated at the sides. In the first instance, we had a composition of wave-motion with river-motion; here we have the coalescence of waves with waves. Where crest and furrow cross each other, the motion is annulled; where furrow and furrow cross, the river is ploughed to a greater depth; and where crest and crest aid each other, we have that astonishing leap of the water which breaks the cohesion of the crests, and tosses them shattered into the air. From the water level the cause of the action is not so easily seen; but from the summit of the cliff the lateral generation of the waves, and their propagation to the centre, are perfectly obvious. If this explanation be correct, the phenomena observed at the Whirlpool Rapids form one of the grandest illustrations of the principle of *interference*. The Nile "cataract," Mr. Huxley informs me, offers more moderate examples of the same action.

At some distance below the Whirlpool Rapids we have the celebrated whirlpool itself. Here the river makes a sudden bend to the northeast, forming nearly a right angle with its previous direction. The water strikes the concave bank with great force, and scoops it incessantly away. A vast basin has been thus formed, in which the sweep of the river prolongs

itself in gyratory currents. Bodies and trees which have come over the falls, are stated to circulate here for days without finding the outlet. From various points of the cliffs above, this is curiously hidden. The rush of the river into the whirlpool is obvious enough; and though you imagine the outlet must be visible, if one existed, you cannot find it. Turning, however, round the bend of the precipice to the northeast, the outlet comes into view.

The Niagara season was over; the chatter of sightseers had ceased, and the scene presented itself as one of holy seclusion and beauty. I went down to the river's edge, where the weird loneliness seemed to increase. The basin is enclosed by high and almost precipitous banks—covered, at the time, with russet woods. A kind of mystery attaches itself to gyrating water, due perhaps to the fact that we are to some extent ignorant of the direction of its force. It is said that at certain points of the whirlpool, pine-trees are sucked down, to be ejected mysteriously elsewhere. The water is of the brightest emerald-green. The gorge through which it escapes is narrow, and the motion of the river swift though silent. The surface is steeply inclined, but it is perfectly unbroken. There are no lateral waves, no ripples with their breaking bubbles to raise a murmur; while the depth is here too great to allow the inequality of the bed to ruffle the surface. Nothing can be more beautiful than this sloping liquid mirror formed by the Niagara, in sliding from the whirlpool.

The green color is, I think, correctly accounted for in the last Fragment.[18] While crossing the Atlantic in 1872–73 I had frequent opportunities of testing the explanation there given.

[18] Fragment. One of the essays in *Fragments of Science*, a collection of John Tyndall's popular scientific papers. The essay referred to is "Voyage to Algeria to Observe the Eclipse."

Looked properly down upon, there are portions of the ocean to which we should hardly ascribe a trace of blue; at the most, a mere hint of indigo reaches the eye. The water, indeed, is practically black, and this is an indication both of its depth and of its freedom from mechanically suspended matter. In small thicknesses water is sensibly transparent to all kinds of light; but, as the thickness increases, the rays of low refrangibility are first absorbed, and after them the other rays. Where, therefore, the water is very deep and very pure, all the colors are absorbed, and such water ought to appear black, as no light is sent from its interior to the eye. The approximation of the Atlantic Ocean to this condition is an indication of its extreme purity.

Throw a white pebble into such water; as it sinks it becomes greener and greener, and, before it disappears, it reaches a vivid blue-green. Break such a pebble into fragments, each of these will behave like the unbroken mass; grind the pebble to powder, every particle will yield its modicum of green; and if the particles be so fine as to remain suspended in the water, the scattered light will be a uniform green. Hence the greenness of shoal water. You go to bed with the black Atlantic around you. You rise in the morning, find it a vivid green, and correctly infer that you are crossing the bank of Newfoundland. Such water is found charged with fine matter in a state of mechanical suspension. The light from the bottom may sometimes come into play, but it is not necessary. A storm can render the water muddy, by rendering the particles too numerous and gross. Such a case occurred towards the close of my visit to Niagara. There had been rain and storm in the upper lake-regions, and the quantity of suspended matter brought down quite extinguished the fascinating green of the Horseshoe.

Nothing can be more superb than the green of the Atlantic waves, when the circumstances are favorable to the exhibition of the color. As long as a wave remains unbroken no color appears; but when the foam just doubles over the crest, like an Alpine snow-cornice, under the cornice we often see a display of the most exquisite green. It is metallic in its brilliancy. But the foam is necessary to its production. The foam is first illuminated, and it scatters the light in all directions; the light which passes through the higher portion of the wave alone reaches the eye, and gives to that portion its matchless color. The folding of the wave, producing as it does a series of longitudinal protuberances and furrows which act like cylindrical lenses, introduces variations in the intensity of the light, and materially enhances its beauty.

6. THE ORIGIN OF NIAGARA

We have now to consider the genesis and proximate destiny of the Falls of Niagara. We may open our way to this subject by a few preliminary remarks upon erosion. Time and intensity are the main factors of geologic change, and they are in a certain sense convertible. A feeble force acting through long periods, and an intense force acting through short ones, may produce approximately the same results. To Dr. Hooker [19] I have been indebted for some specimens of stones, the first examples of which were picked up by Mr. Hackworth [20] on the shores of Lyell's Bay, near Wellington, in New Zealand. They were described by Mr. Travers [21] in the *Transactions of*

[19] Sir Joseph Dalton Hooker (1817-1911). An English botanist and traveller, who wrote on the flowers of New Zealand.

[20] Mr. Hackworth. A British geologist.

[21] William Thomas Locke Travers (1819-1903). Author of *The Stirring Times of T. Rauparaha* (1872), and *From New Zealand to Lake Michigan* (1889).

the New Zealand Institute. Unacquainted with their origin, you would certainly ascribe their forms to human workmanship. They resemble knives and spear-heads, being apparently chiselled off into facets, with as much attention to symmetry as if a tool, guided by human intelligence, had passed over them. But no human instrument has been brought to bear upon these stones. They have been wrought into their present shape by the wind-blown sand of Lyell's Bay. Two winds are dominant here, and they in succession urged the sand against opposite sides of the stone; every little particle of sand chipped away its infinitesimal bit of stone, and in the end sculptured these singular forms.

The Sphinx [22] of Egypt is nearly covered up by the sand of the desert. The neck of the Sphinx is partly cut across, not, as I am assured by Mr. Huxley, by ordinary weathering, but by the eroding action of the fine sand blown against it. In these cases Nature furnishes us with hints which may be taken advantage of in art; and this action of sand has been recently turned to extraordinary account in the United States. When in Boston, I was taken by my courteous and helpful friend, Mr. Josiah Quincey,[23] to see the action of the sand-blast. A kind of hopper containing fine silicious sand was connected with a reservoir of compressed air, the pressure being variable at pleasure. The hopper ended in a long slit, from which the sand was blown. A plate of glass was placed beneath this slit, and caused to pass slowly under it; it came out perfectly depolished, with a bright opalescent glimmer, such as could only be

[22] Sphinx. At Giza, in Egypt, near the great pyramids, is a figure of a recumbent lion with the head of a woman. The figure is 189 feet long and about 66 feet high. The front was uncovered in 1816. Recently the entire figure was uncovered.

[23] Josiah Quincey (1802-1882). Mayor of Boston, 1845-1849. An American statesman and author.

produced by the most careful grinding. Every little particle of sand urged against the glass, having all its energy concentrated on the point of impact, formed there a little pit, the depolished surface consisting of innumerable hollows of this description.

But this was not all. By protecting certain portions of the surface, and exposing others, figures and tracery of any required form could be etched upon the glass. The figures of open iron-work could be thus copied; while wire-gauze placed over the glass produced a reticulated pattern. But it required no such resisting substance as iron to shelter the glass. The patterns of the finest lace could be thus reproduced; the delicate filaments of the lace itself offering a sufficient protection. All these effects have been obtained with a simple model of the sand-blast devised by my assistant. A fraction of a minute suffices to etch upon glass a rich and beautiful lace pattern. Any yielding substance may be employed to protect the glass. By diffusing the shock of the particle, such substances practically destroy the local erosive power. The hand can bear, without inconvenience, a sand-shower which would pulverise glass. Etchings executed on glass with suitable kinds of ink are accurately worked out by the sand-blast. In fact, within certain limits, the harder the surface, the greater is the concentration of the shock, and the more effectual is the erosion. It is not necessary that the sand should be the harder substance of the two; corundum, for example, is much harder than quartz; still, quartz-sand can not only depolish, but actually blow a hole through a plate of corundum. Nay, glass may be depolished by the impact of fine shot; the grains in this case bruising the glass, before they have time to flatten and turn their energy into heat.

And here, in passing, we may tie together one or two appar-

ently unrelated facts. Supposing you turn on, at the lower part of a house, a cock which is fed by a pipe from a cistern at the top of the house, the column of water, from the cistern downwards, is set in motion. By turning off the cock, this motion is stopped; and when the turning off is very sudden, the pipe, if not strong, may be burst by the internal impact of the water. By distributing the turning of the cock over half a second of time, the shock and danger of rupture may be entirely avoided. We have here an example of the concentration of energy in *time*. The sand-blast illustrates the concentration of energy in *space*. The action of flint and steel is an illustration of the same principle. The heat required to generate the spark is intense; and the mechanical action, being moderate, must, to produce fire, be in the highest degree concentrated. This concentration is secured by the collision of hard substances. Calc-spar will not supply the place of flint, nor lead the place of steel, in the production of fire by collision. With the softer substances, the total heat produced may be greater than with the hard ones, but, to produce the spark, the heat must be intensely localised.

We can, however, go far beyond the mere depolishing of glass; indeed I have already said that quartz-sand can wear a hole through corundum. This leads me to express my acknowledgments to General Tilghman,[24] who is the inventor of the sand-blast. To his spontaneous kindness I am indebted for some beautiful illustrations of his process. In one thick plate of glass a figure has been worked out to a depth of ⅜ths of an inch. A second plate, ⅞ths of an inch thick, is entirely perforated. In a circular plate of marble, nearly half an inch thick, open work of most intricate and elaborate description

[24] General B. C. Tilghman. The American inventor of the sand-blast, an improvement on which is now in common use.

has been executed. It would probably take many days to perform this work by any ordinary process; with the sand-blast it was accomplished in an hour. So much for the strength of the blast; its delicacy is illustrated by this beautiful example of line engraving, etched on glass by means of the blast.

This power of erosion, so strikingly displayed when sand is urged by air, renders us better able to conceive its action when urged by water. The erosive power of a river is vastly augmented by the solid matter carried along with it. Sand or pebbles, caught in a river vortex, can wear away the hardest rock; "potholes" and deep cylindrical shafts being thus produced. An extraordinary instance of this kind of erosion is to be seen in the Val Tournanche,[25] above the village of this name. The gorge at Handeck [26] has been thus cut out. Such waterfalls were once frequent in the valleys of Switzerland; for hardly any valley is without one or more transverse barriers of resisting material, over which the river flowing through the valley once fell as a cataract. Near Pontresina,[27] in the Engadin,[28] there is such a case; a hard gneiss there worn away to form a gorge, through which the river from the Morteratsch glacier rushes. The barrier of the Kirchet [29] above Meiringen [30] is also a case in point. Behind it was a lake, derived from the glacier of the Aar, and over the barrier the lake poured its excess of water. Here the rock, being limestone, was in part dissolved; but added to this we had the action of the sand and

[25] Val Tournanche. A valley in the Italian Alps.

[26] Handeck. The cascade of the Aare, in Switzerland, falls into a gorge 240 feet deep.

[27] Pontresina. A village in Switzerland, in the Engadin Valley.

[28] Engadin. A deep mountain valley in Switzerland, through which flows the Inn River.

[29] Kirchet. A granite-covered hill that divides the Hasli-Tal in Switzerland into the Lower and the Upper Valley.

[30] Meiringen. A village in the Aar Valley in Switzerland.

gravel carried along by the water, which, on striking the rock, chipped it away like the particles of the sand-blast. Thus, by solution and mechanical erosion, the great chasm of the Finsteraarschlucht[31] was formed. It is demonstrable that the water which flows at the bottoms of such deep fissures once flowed at the level of their present edges, and tumbled down the lower faces of the barriers. Almost every valley in Switzerland furnishes examples of this kind; the untenable hypothesis of earthquakes, once so readily resorted to in accounting for these gorges, being now for the most part abandoned. To produce the Cañons of Western America, no other cause is needed than the integration of effects individually infinitesimal.

And now we come to Niagara. Soon after Europeans had taken possession of the country, the conviction appears to have arisen that the deep channel of the river Niagara below the falls had been excavated by the cataract. In Mr. Bakewell's[32] *Introduction to Geology,* the prevalence of this belief has been referred to. It is expressed thus by Professor Joseph Henry[33] in the *Transactions of the Albany Institute:* "In viewing the position of the falls, and the features of the country round, it is impossible not to be impressed with the idea that this great natural raceway has been formed by the continued action of the irresistible Niagara, and that the falls, beginning at Lewiston,[34] have, in the course of ages, worn back the rocky strata to their present site." The same view is advocated by Sir Charles Lyell,[35] by Mr. Hall,[36] by M. Agas-

[31] Finsteraarschlucht. The dark gorge of the Aar River, in Switzerland.
[32] See note 13.
[33] Joseph Henry (1797-1878). An American physicist, an investigator of electricity.
[34] Lewiston. A village in the United States, seven miles from Niagara Falls.
[35] Charles Lyell (1797-1875). A great Scotch geologist.
[36] James Hall (1811-1898). An American geologist.

siz,[37] by Professor Ramsay,[38] indeed by most of those who have inspected the place.

A connected image of the origin and progress of the cataract is easily obtained. Walking northward from the village of Niagara Falls by the side of the river, we have to our left the deep and comparatively narrow gorge, through which the Niagara flows. The bounding cliffs of this gorge are from 300 to 350 feet high. We reach the whirlpool, trend to the northeast, and after a little time gradually resume our northward course. Finally, at about seven miles from the present falls, we come to the edge of a declivity, which informs us that we have been hitherto walking on table-land. At some hundreds of feet below us is a comparatively level plain, which stretches to Lake Ontario. The declivity marks the end of the precipitous gorge of the Niagara. Here the river escapes from its steep mural boundaries, and in a widened bed pursues its way to the lake which finally receives its waters.

The fact that in historic times, even within the memory of man, the fall has sensibly receded, prompts the question, How far has this recession gone? At what point did the ledge which thus continually creeps backwards begin its retrograde course? To minds disciplined in such researches the answer has been, and will be—At the precipitous declivity which crossed the Niagara from Lewiston on the American to Queenston on the Canadian side. Over this transverse barrier the united affluents of all the upper lakes once poured their waters, and here the work of erosion began. The dam, moreover, was demonstrably of sufficient height to cause the river above it to submerge Goat Island; and this would perfectly account for the finding by Sir

[37] Alexander Agassiz (1835-1910). A Swiss-American zoölogist and geologist.

[38] Sir Andrew Ramsay (1814-1891). A Scotch geologist.

Charles Lyell, Mr. Hall, and others, in the sand and gravel of the island, the same fluviatile [39] shells as are now found in the Niagara River higher up. It would also account for those deposits along the sides of the river, the discovery of which enabled Lyell, Hall, and Ramsay to reduce to demonstration the popular belief that the Niagara once flowed through a shallow valley.

The physics of the problem of excavation, which I made clear to my mind before quitting Niagara, are revealed by a close inspection of the present Horseshoe Fall. We see evidently that the greatest weight of water bends over the very apex of the Horseshoe. In a passage in his excellent chapter on Niagara Falls, Mr. Hall alludes to this fact. Here we have the most copious and the most violent whirling of the shattered liquid; here the most powerful eddies recoil against the shale. From this portion of the fall, indeed, the spray sometimes rises without solution of continuity to the region of clouds, becoming gradually more attenuated, and passing finally through the condition of true cloud into invisible vapor, which is sometimes reprecipitated higher up. All the phenomena point distinctly to the center of the river as the place of greatest mechanical energy, and from the center the vigor of the fall gradually dies away towards the sides. The Horseshoe form, with the concavity facing downwards, is an obvious and necessary consequence of this action. Right along the middle of the river the apex of the curve pushes its way backwards, cutting along the center a deep and comparatively narrow groove, and draining the sides as it passes them. Hence the remarkable discrepancy between the widths of the Niagara above and below the Horseshoe. All along its course, from Lewiston Heights

[39] Fluviatile. Belonging to a river.

to its present position, the form of the fall was probably that of a horseshoe; for this is merely the expression of the greater depth, and consequently greater excavating power, of the center of the river. The gorge, moreover, varies in width, as the depth of the center of the ancient river varied, being narrowest where that depth was greatest.

The vast comparative erosive energy of the Horseshoe Fall comes strikingly into view when it and the American Fall are compared together. The American branch of the river is cut at a right angle by the gorge of the Niagara. Here the Horseshoe Fall was the real excavator. It cut the rock, and formed the precipice, over which the American Fall tumbles. But since its formation, the erosive action of the American Fall has been almost nil, while the Horseshoe has cut its way for 500 yards across the end of Goat Island, and is now doubling back to excavate its channel parallel to the length of the island. This point, which impressed me forcibly, has not, I have just learned, escaped the acute observation of Professor Ramsay. The river bends; the Horseshoe immediately accommodates itself to the bending, and will follow implicitly the direction of the deepest water in the upper stream. The flexures of the gorge are determined by those of the river channel above it. Were the Niagara center above the fall sinuous, the gorge would obediently follow its sinuosities. Once suggested, no doubt geographers will be able to point out many examples of this action. The Zambesi[40] is thought to present a great difficulty to the erosion theory, because of the sinuosity of the chasm below the Victoria Falls. But, assuming the basalt to

[40] Zambesi. A great river in Africa, flowing into the Indian Ocean. Below the Victoria Falls is a very crooked gorge over 40 miles long and over 400 feet deep.

be of tolerably uniform texture, had the river been examined before the formation of this sinuous channel, the present zigzag course of the gorge below the fall could, I am persuaded, have been predicted, while the sounding of the present river would enable us to predict the course to be pursued by the erosion in the future.

But not only has the Niagara River cut the gorge; it has carried away the chips of its own workshop. The shale, being probably crumbled, is easily carried away. But at the base of the fall we find the huge boulders already described, and by some means or other these are removed down the river. The ice which fills the gorge in winter, and which grapples with the boulders, has been regarded as the transporting agent. Probably it is so to some extent. But erosion acts without ceasing on the abutting points of the boulders, thus withdrawing their support and urging them gradually down the river. Solution also does its portion of the work. That solid matter is carried down is proved by the difference of depths between the Niagara River and Lake Ontario, where the river enters it. The depth falls from 72 feet to 20 feet, in consequence of the deposition of solid matter caused by the diminished motion of the river.

7. THE FUTURE OF NIAGARA

In conclusion, we may say a word regarding the proximate future of Niagara. At the rate of excavation assigned to it by Sir Charles Lyell, namely, a foot a year, five thousand years or so will carry the Horseshoe Fall far higher than Goat Island. As the gorge recedes it will drain, as it has hitherto done, the banks right and left of it, thus leaving a nearly level terrace between Goat Island and the edge of the gorge. Higher up

it will totally drain the American branch of the river; the channel of which in due time will become cultivable land. The American Fall will then be transformed into a dry precipice, forming a simple continuation of the cliffy boundary of the Niagara gorge. At the place occupied by the fall at this moment we shall have the gorge enclosing a right angle, a second whirlpool being the consequence. To those who visit Niagara a few millenniums hence I leave the verification of this prediction. All that can be said is, that if the causes now in action continue to act, it will prove itself literally true.

POSTSCRIPT

A year or so after I had quitted the United States, a man sixty years of age, while engaged in painting one of the bridges which connect Goat Island with the Three Sisters, slipped through the rails of the bridge into the rapids, and was carried impetuously towards the Horseshoe Fall. He was urged against a rock which rose above the water, and with the grasp of desperation he clung to it. The population of the village of Niagara Falls was soon upon the island, and ropes were brought, but there was none to use them. In the midst of the excitement, a tall powerful young fellow was observed making his way silently through the crowd. He reached a rope; selected from the bystanders a number of men, and placed one end of the rope in their hands. The other end he fastened round himself, and choosing a point considerably above that to which the man clung, he plunged into the rapids. He was carried violently downwards, but he caught the rock, secured the old painter and saved him. Newspapers from all parts of the Union poured in upon me, describing this gallant act of my guide Conroy.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 Early Exaggerations about Niagara

1 Explain the full meaning of the first paragraph.
2 What explains differences in the reports of early observers of Niagara?
3 What type of observation is most satisfactory?

2 First General Impressions of Niagara

4 Describe the general appearance of Niagara Falls.
5 What characteristics give beauty to Niagara?
6 How do the parts of the falls differ?
7 Why was Thomas Young unable to appreciate natural scenery?
8 What is the purpose of the article?
9 What gives most satisfaction in viewing natural scenery?

3 Under the Waterfall

10 If you have visited Niagara Falls, tell how conditions there today differ from conditions when the article was written.
11 Point out examples of vivid description.
12 What are some of the effects of sincere enjoyment of natural scenery?
13 What have various poets said about the effects of the enjoyment of natural scenery?
14 What does the article reveal concerning Mr. Tyndall's personality and character?

4 Views of Niagara from the River below the Falls

15 Write a description such as the discoverers of Niagara might have written if they had gone in an Indian canoe close to the falls.

5 The Whirlpool Rapids

16 Point out purely literary elements, and purely scientific elements, in the description of the rapids.
17 What are the causes of the phenomena that appear in the rapids?
18 Why is the whirlpool a romantic place?
19 What accounts for changes of color in various depths and conditions of water?

6 The Origin of Niagara

20 Explain some of the effects of erosion.
21 Explain some of the practical uses of erosion.
22 What results does erosion accomplish in the world of nature?
23 What facts explain the formation of Niagara Falls?
24 What changes may take place in Niagara Falls?
25 What accounts for the various depths of Niagara River?

7 The Future of Niagara

26 What will visitors in various years, far in the future, see when they visit Niagara?
27 Summarize the impressions that the article leaves upon the reader.
28 Relate some of your own experiences or observations at Niagara, or at other cataracts.
29 Explain the course of a brook or river near your own home.

BOOKS FOR FURTHER READING

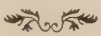
Fragments of Science, John Tyndall, *Appleton,* 1872.
Hours of Exercise in the Alps, John Tyndall, *Appleton,* 1899.
The Forms of Water, John Tyndall, *Appleton,* 1899.
Heat as a Mode of Motion, John Tyndall, *Appleton,* 1905.
Natural Wonders Every Child Should Know, Edwin T. Brewster, *Grosset,* 1915.
Panama and Its Bridge of Water, Stella H. Nida, *Rand,* 1923.
Our Physical World, Elliot R. Downing, 1924.
Ice Ages: The Story of the Earth's Revolutions, Joseph McCabe, *Putnam,* 1922.
Coal, Francis H. Wilson, *Pitman,* 1913.
Wind and Weather, Alexander McAdie, *Macmillan,* 1922.

ON A PIECE OF CHALK

By

THOMAS HENRY HUXLEY

Reprinted from DISCOURSES BIOLOGICAL AND GEOLOGICAL, *by Thomas H. Huxley.*



"The mind is so constituted that it does not willingly rest in facts and immediate causes, but seeks always after a knowledge of the remoter links in the chain of causation."

THOMAS HENRY HUXLEY.

THOMAS HENRY HUXLEY
(1825-1895)

Romantic rise to early success is noteworthy in the case of Thomas Henry Huxley, the biologist. After an irregular school course, but after a childhood of study, he became a physician and surgeon, and served for four years as Assistant Surgeon on *H.M.S. Rattlesnake,* 1846-1850. Without special training, and without suitable apparatus, the young man made original studies of the surface life of the sea, and sent back to England papers, one of which the Royal Society published. On his return, at the age of 25, Mr. Huxley became Fellow of the Royal Society, and at 26 gained the Royal Medal.

In the remainder of his life of 70 years, Mr. Huxley fulfilled the promise made by his early investigations. He resigned from the Navy, and for 31 years served as Professor of Natural History in the Royal School of Mines, and as Fullerian Professor of Physiology at the Royal Institution. He made epoch-making studies in biology, and especially in paleontology, the study of the ancient life of the globe. Through books, papers, and addresses, he became a leader of thought.

His important works are: *Oceanic Hydrozoa* (1859); *Evidence as to Man's Place in Nature* (1863); *Lectures on the Elements of Comparative Anatomy* (1864); *Lessons in Elementary Physiology* (1866); *An Introduction to the Classification of Animals* (1869); *Lay Sermons* (1870); *A Manual of the Anatomy of Vertebrated Animals* (1871); *Critiques and Addresses* (1873); *Physiography* (1877); *A Manual of the Anatomy of Invertebrated Animals* (1877); *The Crayfish* (1880); *Science and Culture* (1881); *A Course of Practical Instruction in Elementary Biology* (with H. M. Martin, 1875); *Essays Upon Some Controverted Questions* (1892); *Evolution and Ethics* (1893).

ON A PIECE OF CHALK

By Thomas Henry Huxley

I. THE CHALK-BEDS OF ENGLAND AND OF OTHER LANDS

IF A well were sunk at our feet in the midst of the city of Norwich,[1] the diggers would very soon find themselves at work in that white substance almost too soft to be called rock, with which we are all familiar as "chalk."

Not only here, but over the whole county of Norfolk,[2] the well-sinker might carry his shaft down many hundred feet without coming to the end of the chalk; and, on the sea-coast, where the waves have pared away the face of the land which breasts them, the scarped faces of the high cliffs are often wholly formed of the same material. Northward, the chalk may be followed as far as Yorkshire;[3] on the south coast it appears abruptly in the picturesque western bays of Dorset,[4] and breaks into the Needles of the Isle of Wight;[5] while on the shores of Kent [6] it supplies that long line of white cliffs to which England owes her name of Albion.[7]

Were the thin soil which covers it all washed away, a curved band of white chalk, here broader, and there narrower, might

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[1] Norwich. An English city, the capital of the county of Norfolk.

[2] Norfolk. An eastern county of England, bordered by the North Sea.

[3] Yorkshire. A county in the north of England.

[4] Dorset. A county in the south of England.

[5] Needles of the Isle of Wight. A group of three sharp chalk rocks, on the Isle of Wight, south of England.

[6] Kent. A county in the southeastern part of England.

[7] Albion. A name applied to England. It is derived from the Greek and Latin, and means "The White Land."

be followed diagonally across England from Lulworth in Dorset, to Flamborough Head in Yorkshire [8]—a distance of over 280 miles as the crow flies. From this band to the North Sea, on the east, and the Channel, on the south, the chalk is largely hidden by other deposits; but, except in the Weald of Kent,[9] and Sussex, it enters into the very foundation of all the southeastern counties.

Attaining, as it does in some places, a thickness of more than a thousand feet, the English chalk must be admitted to be a mass of considerable magnitude. Nevertheless, it covers but an insignificant portion of the whole area occupied by the chalk formation of the globe, much of which has the same general characters as ours, and is found in detached patches, some less, and others more extensive, than the English. Chalk occurs in northwest Ireland; it stretches over a large part of France,—the chalk which underlies Paris being, in fact, a continuation of that of the London basin; it runs through Denmark and Central Europe, and extends southward to North Africa; while eastward it appears in the Crimea and in Syria, and may be traced as far as the shores of the Sea of Aral, in Central Asia. If all the points at which true chalk occurs were circumscribed, they would lie within an irregular oval about 3,000 miles in long diameter—the area of which would be as great as that of Europe, and would many times exceed that of the largest existing inland sea—the Mediterranean.

Thus the chalk is no unimportant element in the masonry of the earth's crust, and it impresses a peculiar stamp, varying

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[8] Lulworth in Dorset, to Flamborough Head in Yorkshire. A line from the section called Lulworth to the cape called Flamborough Head would cut diagonally across the length of England.

[9] Weald of Kent. The Weald is a section of southeastern England, including the counties of Kent and Sussex, and parts of the counties of Surrey and Hampshire.

with the conditions to which it is exposed, on the scenery of the districts in which it occurs. The undulating downs[10] and rounded coombs,[11] covered with sweet-grassed turf, of our inland chalk country, have a peacefully domestic and mutton-suggesting prettiness, but can hardly be called either grand or beautiful. But on our southern coasts, the wall-sided cliffs, many hundred feet high, with vast needles and pinnacles standing out in the sea, sharp and solitary enough to serve as perches for the wary cormorant, confer a wonderful beauty and grandeur upon the chalk headlands. And, in the East, chalk has its share in the formation of some of the most venerable of mountain ranges, such as the Lebanon.

2. THE CHEMICAL NATURE OF CHALK

What is this wide-spread component of the surface of the earth? and whence did it come?

You may think this no very hopeful inquiry. You may not unnaturally suppose that the attempt to solve such problems as these can lead to no result, save that of entangling the inquirer in vague speculations, incapable of refutation and of verification. If such were really the case, I should have selected some other subject than a "piece of chalk" for my discourse. But, in truth, after much deliberation, I have been unable to think of any topic which would so well enable me to lead you to see how solid is the foundation upon which some of the most startling conclusions of physical science rest.

A great chapter of the history of the world is written in the chalk. Few passages in the history of man can be supported by such an overwhelming mass of direct and indirect evidence as that which testifies to the truth of the fragment of

[10] Downs. Hilly land near the sea.
[11] Coombs. Hollows in hills.

the history of the globe, which I hope to enable you to read, with your own eyes, tonight. Let me add, that few chapters of human history have a more profound significance for ourselves. I weigh my words well when I assert, that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches-pocket, though ignorant of all other history, is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better, conception of this wonderful universe, and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of Nature.

The language of the chalk is not hard to learn, not nearly so hard as Latin, if you only want to get at the broad features of the story it has to tell; and I propose that we now set to work to spell that story out together.

We all know that if we "burn" chalk the result is quicklime. Chalk, in fact, is a compound of carbonic acid gas, and lime, and when you make it very hot the carbonic acid flies away and the lime is left. By this method of procedure we see the lime, but we do not see the carbonic acid. If, on the other hand, you were to powder a little chalk and drop it into a good deal of strong vinegar, there would be a great bubbling and fizzing, and, finally, a clear liquid, in which no sign of chalk would appear. Here you see the carbonic acid in the bubbles; the lime, dissolved in the vinegar, vanishes from sight. There are a great many other ways of showing that chalk is essentially nothing but carbonic acid and quicklime. Chemists enunciate the result of all the experiments which prove this, by stating that chalk is almost wholly composed of "carbonate of lime."

It is desirable for us to start from the knowledge of this

fact, though it may not seem to help us very far towards what we seek. For carbonate of lime is a widely-spread substance, and is met with under very various conditions. All sorts of limestones are composed of more or less pure carbonate of lime. The crust which is often deposited by waters which have drained through limestone rocks, in the form of what are called stalagmites and stalactites,[12] is carbonate of lime. Or, to take a more familiar example, the fur on the inside of a tea-kettle is carbonate of lime; and, for anything chemistry tells us to the contrary, the chalk might be a kind of gigantic fur upon the bottom of the earth-kettle, which is kept pretty hot below.

3. CHALK UNDER THE MICROSCOPE

Let us try another method of making the chalk tell us its own history. To the unassisted eye chalk looks simply like a very loose and open kind of stone. But it is possible to grind a slice of chalk down so thin that you can see through it—until it is thin enough, in fact, to be examined with any magnifying power that may be thought desirable. A thin slice of the fur of a kettle might be made in the same way. If it were examined microscopically, it would show itself to be a more or less distinctly laminated mineral substance, and nothing more.

But the slice of chalk presents a totally different appearance when placed under the microscope. The general mass of it is made up of very minute granules; but, imbedded in this matrix, are innumerable bodies, some smaller and some larger, but, on a rough average, not more than a hundredth of an inch in diameter, having a well-defined shape and structure.

[12] Stalagmites and stalactites. Calcium formations in caverns, the stalagmites being formed on the floor, and the stalactites hanging from the roofs.

A cubic inch of some specimens of chalk may contain hundreds of thousands of these bodies, compacted together with incalculable millions of the granules.

The examination of a transparent slice gives a good notion of the manner in which the components of the chalk are arranged, and of their relative proportions. But, by rubbing up some chalk with a brush in water and then pouring off the milky fluid, so as to obtain sediments of different degrees of fineness, the granules and the minute rounded bodies may be pretty well separated from one another, and submitted to microscopic examination, either as opaque or as transparent objects. By combining the views obtained in these various methods, each of the rounded bodies may be proved to be a beautifully-constructed calcareous fabric, made up of a number of chambers, communicating freely with one another. The chambered bodies are of various forms. One of the commonest is something like a badly-grown raspberry, being formed of a number of nearly globular chambers of different sizes congregated together. It is called *Globigerina,* and some specimens of chalk consist of little else than *Globigerinæ* and granules. Let us fix our attention upon the *Globigerina.* It is the spoor [13] of the game we are tracking. If we can learn what it is and what are the conditions of its existence, we shall see our way to the origin and past history of the chalk.

A suggestion which may naturally enough present itself is, that these curious bodies are the result of some process of aggregation which has taken place in the carbonate of lime; that, just as in winter, the rime on our windows simulates the most delicate and elegantly arborescent foliage—proving that the mere mineral water may, under certain conditions, assume the outward form of organic bodies—so this mineral substance,

[13] Spoor. Trail.

carbonate of lime, hidden away in the bowels of the earth, has taken the shape of these chambered bodies. I am not raising a merely fanciful and unreal objection. Very learned men, in former days, have even entertained the notion that all the formed things found in rocks are of this nature; and if no such conception is at present held to be admissible, it is because long and varied experience has now shown that mineral matter never does assume the form and structure we find in fossils. If any one were to try to persuade you that an oyster-shell (which is also chiefly composed of carbonate of lime) had crystallized out of sea-water, I suppose you would laugh at the absurdity. Your laughter would be justified by the fact that all experience tends to show that oyster-shells are formed by the agency of oysters, and in no other way. And if there were no better reasons, we should be justified, on like grounds, in believing that *Globigerina* is not the product of anything but vital activity.

4. LIVING MAKERS OF CHALK

Happily, however, better evidence in proof of the organic nature of the *Globigerinæ* than that of analogy is forthcoming. It so happens that calcareous skeletons, exactly similar to the *Globigerinæ* of the chalk, are being formed, at the present moment, by minute living creatures, which flourish in multitudes, literally more numerous than the sands of the sea-shore, over a large extent of that part of the earth's surface which is covered by the ocean.

The history of the discovery of these living *Globigerinæ,* and of the part which they play in rock building, is singular enough. It is a discovery which, like others of no less scientific importance, has arisen, incidentally, out of work devoted to very

different and exceedingly practical interests. When men first took to the sea, they speedily learned to look out for shoals and rocks; and the more the burthen of their ships increased, the more imperatively necessary it became for sailors to ascertain with precision the depth of the waters they traversed. Out of this necessity grew the use of the lead and sounding line; and, ultimately, marine-surveying, which is the recording of the form of coasts and of the depth of the sea, as ascertained by the sounding-lead, upon charts.

At the same time, it became desirable to ascertain and to indicate the nature of the sea-bottom, since this circumstance greatly affects its goodness as holding ground for anchors. Some ingenious tar, whose name deserves a better fate than the oblivion into which it has fallen, attained this object by "arming" the bottom of the lead with a lump of grease, to which more or less of the sand or mud, or broken shells, as the case might be, adhered, and was brought to the surface. But, however well adapted such an apparatus might be for rough nautical purposes, scientific accuracy could not be expected from the armed lead, and to remedy its defects (especially when applied to sounding in great depths) Lieut. Brooke,[14] of the American Navy, some years ago invented a most ingenious machine, by which a considerable portion of the superficial layer of the sea-bottom can be scooped out and brought up from any depth to which the lead descends. In 1853, Lieut. Brooke obtained mud from the bottom of the North Atlantic, between Newfoundland and the Azores, at a depth of more than 10,000 feet, or two miles, by the help of this sounding apparatus. The specimens were sent for examina-

[14] Lieutenant B. Brooke, United States Naval officer. Inventor of a deep-sea sounding apparatus. In 1856 he surveyed the Sea of Kamschatka, and reached a depth of 16,200 feet.

tion to Ehrenberg[15] of Berlin, and to Bailey[16] of West Point, and those able microscopists found that this deep-sea mud was almost entirely composed of the skeletons of living organisms —the greater proportion of these being just like the *Globigerinæ* already known to occur in the chalk.

Thus far, the work had been carried on simply in the interests of science, but Lieut. Brooke's method of sounding acquired a high commercial value, when the enterprise of laying down the telegraph-cable between this country and the United States was undertaken. For it became a matter of immense importance to know, not only the depth of the sea over the whole line along which the cable was to be laid, but the exact nature of the bottom, so as to guard against chances of cutting or fraying the strands of that costly rope. The Admiralty[17] consequently ordered Captain Dayman,[18] an old friend and shipmate of mine, to ascertain the depth over the whole line of the cable, and to bring back specimens of the bottom. In former days, such a command as this might have sounded very much like one of the impossible things which the young Prince in the Fairy Tales is ordered to do before he can obtain the hand of the Princess. However, in the months of June and July, 1857, my friend performed the task assigned to him with great expedition and precision, without, so far as I know, having met with any reward of that kind. The specimens of Atlantic mud which he procured were sent to me to be examined and reported upon.

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[15] Christian Ehrenberg (1795-1876). A German naturalist who made especial studies of infusoria, the microscopic life of the sea.

[16] Jacob Whitman Bailey (1811-1857). An American naturalist, a graduate of West Point, and Professor of chemistry, mineralogy and geology at West Point. He developed miscroscopical research in America.

[17] Admiralty. The department in charge of naval affairs.

[18] Lieutenant Commander Joseph Dayman. In 1857 author of a *Report on Deep-Sea Soundings in the Atlantic Ocean.*

The result of all these operations is, that we know the contours and the nature of the surface-soil covered by the North Atlantic for a distance of 1,700 miles from east to west, as well as we know that of any part of the dry land. It is a prodigious plain—one of the widest and most even plains in the world. If the sea were drained off, you might drive a waggon all the way from Valentia, on the west coast of Ireland, to Trinity Bay, in Newfoundland. And, except upon one sharp incline about 200 miles from Valentia, I am not quite sure that it would even be necessary to put the skid on, so gentle are the ascents and descents upon that long route. From Valentia the road would lie down-hill for about 200 miles to the point at which the bottom is now covered by 1,700 fathoms of sea-water. Then would come the central plain, more than a thousand miles wide, the inequalities of the surface of which would be hardly perceptible, though the depth of water upon it now varies from 10,000 to 15,000 feet; and there are places in which Mont Blanc might be sunk without showing its peak above water. Beyond this, the ascent on the American side commences, and gradually leads, for about 300 miles, to the Newfoundland shore.

Almost the whole of the bottom of this central plain (which extends for many hundred miles in a north and south direction) is covered by a fine mud, which, when brought to the surface, dries into a grayish white friable substance. You can write with this on a blackboard, if you are so inclined; and, to the eye, it is quite like very soft, grayish chalk. Examined chemically, it proves to be composed almost wholly of carbonate of lime; and if you make a section of it, in the same way as that of the piece of chalk was made, and view it with the microscope, it presents innumerable *Globigerinæ* embedded

in a granular matrix. Thus this deep-sea mud is substantially chalk. I say substantially, because there are a good many minor differences; but as these have no bearing on the question immediately before us,—which is the nature of the *Globigerinæ* of the chalk,—it is unnecessary to speak of them.

Globigerinæ of every size, from the smallest to the largest, are associated together in the Atlantic mud, and the chambers of many are filled by a soft animal matter. This soft substance is, in fact, the remains of the creature to which the *Globigerina* shell, or rather skeleton, owes its existence—and which is an animal of the simplest imaginable description. It is, in fact, a mere particle of living jelly, without defined parts of any kind—without a mouth, nerves, muscles, or distinct organs, and only manifesting its vitality to ordinary observation by thrusting out and retracting from all parts of its surface, long filamentous processes, which serve for arms and legs. Yet this amorphous [19] particle, devoid of everything which, in the higher animals, we call organs, is capable of feeding, growing, and multiplying; of separating from the ocean the small proportion of carbonate of lime which is dissolved in sea-water; and of building up that substance into a skeleton for itself, according to a pattern which can be imitated by no other known agency.

The notion that animals can live and flourish in the sea, at the vast depths from which apparently living *Globigerinæ* have been brought up, does not agree very well with our usual conceptions respecting the conditions of animal life; and it is not so absolutely impossible as it might at first sight appear to be, that the *Globigerinæ* of the Atlantic sea-bottom do not live and die where they are found.

[19] Amorphous. Shapeless.

5. CHALK, THE MUD OF AN ANCIENT SEA

As I have mentioned, the soundings from the great Atlantic plain are almost entirely made up of *Globigerinæ,* with the granules which have been mentioned, and some few other calcareous shells; but a small percentage of the chalky mud—perhaps at most some five per cent. of it—is of a different nature, and consists of shells and skeletons composed of silex, or pure flint. These silicious bodies belong partly to the lowly vegetable organisms which are called *Diatomaceæ,* and partly to the minute, and extremely simple, animals, termed *Radiolaria.* It is quite certain that these creatures do not live at the bottom of the ocean, but at its surface—where they may be obtained in prodigious numbers by the use of a properly constructed net. Hence it follows that these silicious organisms, though they are not heavier than the lightest dust, must have fallen, in some cases, through fifteen thousand feet of water, before they reached their final resting-place on the ocean floor. And considering how large a surface these bodies expose in proportion to their weight, it is probable that they occupy a great length of time in making their burial journey from the surface of the Atlantic to the bottom.

But if the *Radiolaria* and Diatoms are thus rained upon the bottom of the sea, from the superficial layer of its waters in which they pass their lives, it is obviously possible that the *Globigerinæ* may be similarly derived; and if they were so, it would be much more easy to understand how they obtain their supply of food than it is at present. Nevertheless, the positive and negative evidence all points the other way. The skeletons of the full-grown, deep-sea *Globigerinæ* are so remarkably solid and heavy in proportion to their surface as to seem little fitted for floating; and, as a matter of fact, they are

not to be found along with the Diatoms and *Radiolaria* in the uppermost stratum of the open ocean. It has been observed, again, that the abundance of *Globigerinæ,* in proportion to other organisms, of like kind, increases with the depth of the sea; and that deep-water *Globigerinæ* are larger than those which live in shallower parts of the sea; and such facts negative the supposition that these organisms have been swept by currents from the shallows into the deeps of the Atlantic. It therefore seems to be hardly doubtful that these wonderful creatures live and die at the depths in which they are found.[20]

However, the important points for us are, that the living *Globigerinæ* are exclusively marine animals, the skeletons of which abound at the bottom of deep seas; and that there is not a shadow of reason for believing that the habits of the *Globigerinæ* of the chalk differed from those of the existing species. But if this be true, there is no escaping the conclusion that the chalk itself is the dried mud of an ancient deep sea.

In working over the soundings collected by Captain Dayman, I was surprised to find that many of what I have called the "granules" of that mud were not, as one might have been tempted to think at first, the mere powder and waste of *Globigerinæ,* but that they had a definite form and size. I termed these bodies "coccoliths," and doubted their organic

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[20] "During the cruise of H.M.S. *Bulldog,* commanded by Sir Leopold McClintock, in 1860, living starfish were brought up, clinging to the lowest part of the sounding-line, from a depth of 1,260 fathoms, midway between Cape Farewell, in Greenland, and the Rockall banks. Dr. Wallich ascertained that the sea-bottom at this point consisted of the ordinary *Globigerina* ooze, and that the stomachs of the starfishes were full of *Globigerinæ.* This discovery removes all objections to the existence of living *Globigerinæ* at great depths, which are based upon the supposed difficulty of maintaining animal life under such conditions; and it throws the burden of proof upon those who object to the supposition that the *Globigerinæ* live and die where they are found." *Huxley's note.*

nature. Dr. Wallich [21] verified my observation, and added the interesting discovery that, not unfrequently, bodies similar to these "coccoliths" were aggregated together into spheroids, which he termed "coccospheres." So far as we knew, these bodies, the nature of which is extremely puzzling and problematical, were peculiar to the Atlantic soundings. But, a few years ago, Mr. Sorby,[22] in making a careful examination of the chalk by means of thin sections and otherwise, observed, as Ehrenberg had done before him, that much of its granular basis possesses a definite form. Comparing these formed particles with those in the Atlantic soundings, he found the two to be identical; and thus proved that the chalk, like the surroundings, contains these mysterious coccoliths and coccospheres. Here was a further and most interesting confirmation, from internal evidence, of the essential identity of the chalk with modern deep-sea mud. *Globigerinæ,* coccoliths, and coccospheres are found as the chief constituents of both, and testify to the general similarity of the conditions under which both have been formed.

The evidence furnished by the hewing, facing, and superposition of the stones of the Pyramids, that these structures were built by men, has no greater weight than the evidence that the chalk was built by *Globigerinæ;* and the belief that those ancient pyramid-builders were terrestrial and air-breathing creatures like ourselves, is not better based than the conviction that the chalk-makers lived in the sea. But as our belief in the building of the Pyramids by men is not only grounded on the internal evidence afforded by these struc-

[21] G. C. Wallich (1786-1854). A Danish botanist, Naturalist to the *Bulldog* Sounding Expedition under Sir Leopold McClintock. Author of *The North Atlantic Sea Bed.*

[22] Henry Clifton Sorby (1826-1908). An English geologist who began microscopic study of rocks.

tures, but gathers strength from multitudinous collateral proofs, and is clinched by the total absence of any reason for a contrary belief; so the evidence drawn from the *Globigerinæ* that the chalk is an ancient sea-bottom, is fortified by innumerable independent lines of evidence; and our belief in the truth of the conclusion to which all positive testimony tends, receives the like negative justification from the fact that no other hypothesis has a shadow of foundation.

6. PROOFS OF THE METHOD OF CHALK DEPOSIT

It may be worth while briefly to consider a few of these collateral proofs that the chalk was deposited at the bottom of the sea. The great mass of the chalk is composed, as we have seen, of the skeletons of *Globigerinæ,* and other simple organisms, imbedded in granular matter. Here and there, however, this hardened mud of the ancient sea reveals the remains of higher animals which have lived and died, and left their hard parts in the mud, just as the oysters die and leave their shells behind them, in the mud of the present seas.

There are, at the present day, certain groups of animals which are never found in fresh waters, being unable to live anywhere but in the sea. Such are the corals; those corallines which are called *Polyzoa;* those creatures which fabricate the lamp-shells, and are called *Brachiopoda;* the pearly *Nautilus,* and all animals allied to it; and all the forms of sea-urchins and starfishes. Not only are all these creatures confined to salt water at the present day; but, so far as our records of the past go, the conditions of their existence have been the same: hence, their occurrence in any deposit is as strong evidence as can be obtained, that that deposit was formed in the sea. Now the remains of animals of all the kinds which have been enumerated, occur in the chalk, in greater or less abun-

dance; while not one of those forms of shell-fish which are characteristic of fresh water has yet been observed in it.

When we consider that the remains of more than three thousand distinct species of aquatic animals have been discovered among the fossils of the chalk, that the great majority of them are of such forms as are now met with only in the sea, and that there is no reason to believe that any one of them inhabited fresh water—the collateral evidence that the chalk represents an ancient sea-bottom acquires as great force as the proof derived from the nature of the chalk itself. I think you will now allow that I did not overstate my case when I asserted that we have as strong grounds for believing that all the vast area of dry land, at present occupied by the chalk, was once at the bottom of the sea, as we have for any matter of history whatever; while there is no justification for any other belief.

No less certain it is that the time during which the countries we now call southeast England, France, Germany, Poland, Russia, Egypt, Arabia, Syria, were more or less completely covered by a deep sea, was of considerable duration. We have already seen that the chalk is, in places, more than a thousand feet thick. I think you will agree with me, that it must have taken some time for the skeletons of animalcules of a hundredth of an inch in diameter to heap up such a mass as that. I have said that throughout the thickness of the chalk the remains of other animals are scattered. These remains are often in the most exquisite state of preservation. The valves of the shell-fishes are commonly adherent; the long spines of some of the sea-urchins, which would be detached by the smallest jar, often remain in their places. In a word, it is certain that these animals have lived and died when the place which they now occupy was the surface of as much of

the chalk as had then been deposited; and that each has been covered up by the layer of *Globigerina* mud, upon which the creatures imbedded a little higher up have, in like manner, lived and died. But some of these remains prove the existence of reptiles of vast size in the chalk sea. These lived their time, and had their ancestors and descendants, which assuredly implies time, reptiles being of slow growth.

7. THE SLOWNESS OF CHALK DEPOSIT

There is more curious evidence, again, that the process of covering up, or, in other words, the deposit of *Globigerina* skeletons, did not go on very fast. It is demonstrable that an animal of the cretaceous[23] sea might die, that its skeleton might lie uncovered upon the sea-bottom long enough to lose all its outward coverings and appendages by putrefaction; and that, after this had happened, another animal might attach itself to the dead and naked skeleton, might grow to maturity, and might itself die before the calcareous mud had buried the whole.

Cases of this kind are admirably described by Sir Charles Lyell.[24] He speaks of the frequency with which geologists find in the chalk a fossilized sea-urchin, to which is attached the lower valve of a *Crania.* This is a kind of shell-fish, with a shell composed of two pieces, of which, as in the oyster, one is fixed and the other free.

"The upper valve is almost invariably wanting, though occasionally found in a perfect state of preservation in the white chalk at some distance. In this case, we see clearly that the sea-urchin first lived from youth to age, then died and lost

[23] Cretaceous. The geological period in which the great chalk deposits were made.

[24] Sir Charles Lyell (1797-1875). A Scotch geologist.

its spines, which were carried away. Then the young *Crania* adhered to the bared shell, grew and perished in its turn; after which, the upper valve was separated from the lower, before the *Echinus* became enveloped in chalky mud."

A specimen in the Museum of Practical Geology, in London, still further prolongs the period which must have elapsed between the death of the sea-urchin, and its burial by the *Globigerinæ*. For the outward face of the valve of a *Crania,* which is attached to a sea-urchin (*Micraster*), is itself overrun by an incrusting coralline, which spreads thence over more or less of the surface of the sea-urchin. It follows that, after the upper valve of the *Crania* fell off, the surface of the attached valve must have remained exposed long enough to allow of the growth of the whole coralline, since corallines do not live embedded in mud.

The progress of knowledge may, one day, enable us to deduce from such facts as these the maximum rate at which the chalk can have accumulated, and thus to arrive at the minimum duration of the chalk period. Suppose that the valve of the *Crania* upon which a coralline has fixed itself in the way just described, is so attached to the sea-urchin that no part of it is more than an inch above the face upon which the sea-urchin rests. Then, as the coralline could not have fixed itself, if the *Crania* had been covered up with chalk mud, and could not have lived had itself been so covered, it follows, that an inch of chalk mud could not have accumulated within the time between the death and decay of the soft parts of the sea-urchin and the growth of the coralline to the full size which it has attained. If the decay of the soft parts of the sea-urchin; the attachment, growth to maturity, and decay of the *Crania;* and the subsequent attachment and growth of the coralline, took a year (which is a low estimate enough), the accumu-

lation of the inch of chalk must have taken more than a year: and the deposit of a thousand feet of chalk must, consequently, have taken more than twelve thousand years.

The foundation of all this calculation is, of course, a knowledge of the length of time the *Crania* and the coralline needed to attain their full size; and, on this head, precise knowledge is at present wanting. But there are circumstances which tend to show, that nothing like an inch of chalk has accumulated during the life of a *Crania;* and, on any probable estimate of the length of that life, the chalk period must have had a much longer duration than that thus roughly assigned to it.

8. THE DATE OF CHALK DEPOSITS

Thus, not only is it certain that the chalk is the mud of an ancient sea-bottom; but it is no less certain, that the chalk sea existed during an extremely long period, though we may not be prepared to give a precise estimate of the length of that period in years. The relative duration is clear, though the absolute duration may not be definable. The attempt to affix any precise date to the period at which the chalk sea began, or ended, its existence, is baffled by difficulties of the same kind. But the relative age of the cretaceous epoch may be determined with as great ease and certainty as the long duration of that epoch.

You will have heard of the interesting discoveries recently made, in various parts of Western Europe, of flint implements, obviously worked into shape by human hands, under circumstances which show conclusively that man is a very ancient denizen of these regions. It has been proved that the whole populations of Europe, whose existence has been revealed to us in this way, consisted of savages, such as the Esquimaux are now; that, in the country which is now France, they

hunted the reindeer, and were familiar with the ways of the mammoth and the bison. The physical geography of France was in those days different from what it is now—the river Somme, for instance, having cut its bed a hundred feet deeper between that time and this; and, it is probable, that the climate was more like that of Canada or Siberia, than that of Western Europe.

The existence of these people is forgotten even in the traditions of the oldest historical nations. The name and fame of them had utterly vanished until a few years back; and the amount of physical change which has been effected since their day renders it more than probable that, venerable as are some of the historical nations, the workers of the chipped flints of Hoxne[25] or of Amiens[26] are to them, as they are to us, in point of antiquity. But, if we assign to these hoar relics of long-vanished generations of men the greatest age that can possibly be claimed for them, they are not older than the drift, or boulder clay, which, in comparison with the chalk, is but a very juvenile deposit. You need go no further than your own sea-board for evidence of this fact. At one of the most charming spots on the coast of Norfolk, Cromer,[27] you will see the boulder clay forming a vast mass, which lies upon the chalk, and must consequently have come into existence after it. Huge boulders of chalk are, in fact, included in the clay, and have evidently been brought to the position they now occupy by the same agency as that which has planted blocks of syenite from Norway side by side with them.

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[25] Hoxne. A place in Suffolk, in eastern England, where very early human remains were found.

[26] Amiens. A city in the north of France, near which very early human remains were found.

[27] Cromer. A shore resort on the eastern coast of England, noted for its sandy beach, and its cliffs, 60-200 feet high.

The chalk, then, is certainly older than the boulder clay. If you ask how much, I will again take you no further than the same spot upon your own coasts for evidence. I have spoken of the boulder clay and drift as resting upon the chalk. That is not strictly true. Interposed between the chalk and the drift is a comparatively insignificant layer, containing vegetable matter. But that layer tells a wonderful history. It is full of stumps of trees standing as they grew. Fir-trees are there with their cones, and hazel-bushes with their nuts; there stand the stools of oak and yew trees, beeches and alders. Hence this stratum is appropriately called the "forest-bed."

It is obvious that the chalk must have been unheaved and converted into dry land, before the timber trees could grow upon it. As the bolls of some of these trees are from two to three feet in diameter, it is no less clear that the dry land thus formed remained in the same condition for long ages. And not only do the remains of stately oaks and well-grown firs testify to the duration of this condition of things, but additional evidence to the same effect is afforded by the abundant remains of elephants, rhinoceroses, hippopotamuses, and other great wild beasts, which it has yielded to the zealous search of such men as the Rev. Mr. Gunn.[28] When you look at such a collection as he has formed, and bethink you that these elephantine bones did veritably carry their owners about, and these great grinders crunch, in the dark woods of which the forest-bed is now the only trace, it is impossible not to feel that they are as good evidence of the lapse of time as the annual rings of the tree stumps.

Thus there is a writing upon the wall of cliffs at Cromer, and whoso runs may read it. It tells us, with an authority

[28] Rev. Mr. Gunn (1800-1881). An English naturalist who supplied the British Museum with valuable animals and plants from Tasmania.

which cannot be impeached, that the ancient sea-bed of the chalk sea was raised up, and remained dry land, until it was covered with forest, stocked with the great game the spoils of which have rejoiced your geologists. How long it remained in that condition cannot be said; but "the whirligig of time brought its revenges" in those days as in these. That dry land, with the bones and teeth of generations of long-lived elephants, hidden away among the gnarled roots and dry leaves of its ancient trees, sank gradually to the bottom of the icy sea, which covered it with huge masses of drift and boulder clay. Sea-beasts, such as the walrus, now restricted to the extreme north, paddled about where birds had twittered among the topmost twigs of the fir-trees. How long this state of things endured we know not, but at length it came to an end. The upheaved glacial mud hardened into the soil of modern Norfolk. Forests grew once more; the wolf and the beaver replaced the reindeer and the elephant; and at length what we call the history of England dawned.

Thus you have, within the limits of your own county, proof that the chalk can justly claim a very much greater antiquity than even the oldest physical traces of mankind. But we may go further and demonstrate, by evidence of the same authority as that which testifies to the existence of the father of men, that the chalk is vastly older than Adam himself. The Book of Genesis informs us that Adam, immediately upon his creation, and before the appearance of Eve, was placed in the Garden of Eden. The problem of the geographical position of Eden has greatly vexed the spirits of the learned in such matters, but there is one point respecting which, so far as I know, no commentator has ever raised a doubt. This is, that of the four rivers which are said to run out of it, Euphrates and Hiddekel are identical with the rivers now known by the

names of Euphrates and Tigris. But the whole country in which these mighty rivers take their origin, and through which they run, is composed of rocks which are either of the same age as the chalk, or of later date. So that the chalk must not only have been formed, but, after its formation, the time required for the deposit of these later rocks, and for their upheaval into dry land, must have elapsed, before the smallest brook which feeds the swift stream of "the great river, the river of Babylon," began to flow.

9. CHANGES INDICATED BY CHALK

Thus, evidence which cannot be rebutted, and which need not be strengthened, though if time permitted I might indefinitely increase its quantity, compels you to believe that the earth, from the time of the chalk to the present day, has been the theater of a series of changes as vast in their amount, as they were slow in their progress. The area on which we stand has been first sea and then land, for at least four alternations; and has remained in each of these conditions for a period of great length.

Nor have these wonderful metamorphoses of sea into land, and of land into sea, been confined to one corner of England. During the chalk period, or "cretaceous epoch," not one of the present great physical features of the globe was in existence. Our great mountain ranges, Pyrenees, Alps, Himalayas, Andes, have all been upheaved since the chalk was deposited, and the cretaceous sea flowed over the sites of Sinai and Ararat. All this is certain, because rocks of cretaceous, or still later, date have shared in the elevatory movements which gave rise to these mountain chains; and may be found perched up, in some cases, many thousand feet high upon their flanks. And evidence of equal cogency demonstrates that, though, in

Norfolk, the forest-bed rests directly upon the chalk, yet it does so, not because the period at which the forest grew immediately followed that at which the chalk was formed, but because an immense lapse of time, represented elsewhere by thousands of feet of rock, is not indicated at Cromer.

I must ask you to believe that there is no less conclusive proof that a still more prolonged succession of similar changes occurred, before the chalk was deposited. Nor have we any reason to think that the first term in the series of these changes is known. The oldest sea-beds preserved to us are sands, and mud, and pebbles, the wear and tear of rocks which were formed in still older oceans.

But, great as is the magnitude of these physical changes of the world, they have been accompanied by a no less striking series of modifications in its living inhabitants. All the great classes of animals, beasts of the field, fowls of the air, creeping things, and things which dwell in the waters, flourished upon the globe long ages before the chalk was deposited. Very few, however, if any, of these ancient forms of animal life were identical with those which now live. Certainly not one of the higher animals was of the same species as any of those now in existence. The beasts of the field, in the days before the chalk, were not our beasts of the field, nor the fowls of the air such as those which the eye of man has seen flying, unless his antiquity dates infinitely further back than we at present surmise. If we could be carried back into those times, we should be as one suddenly set down in Australia before it was colonized. We should see mammals, birds, reptiles, fishes, insects, snails, and the like, clearly recognizable as such, and yet not one of them would be just the same as those with which we are familiar, and many would be extremely different.

From that time to the present, the population of the world

has undergone slow and gradual, but incessant, changes. There has been no grand catastrophe—no destroyer has swept away the forms of life of one period, and replaced them by a totally new creation: but one species has vanished and another has taken its place; creatures of one type of structure have diminished, those of another have increased, as time has passed on. And thus, while the differences between the living creatures of the time before the chalk and those of the present day appear startling, if placed side by side, we are led from one to the other by the most gradual progress, if we follow the course of nature through the whole series of those relics of her operations which she has left behind. It is by the population of the chalk sea that the ancient and the modern inhabitants of the world are most completely connected. The groups which are dying out flourish, side by side, with the groups which are now the dominant forms of life. Thus the chalk contains remains of those strange flying and swimming reptiles, the pterodactyl,[29] the ichthyosaurus,[30] and the plesiosaurus,[31] which are found in no later deposits, but abounded in preceding ages. The chambered shells called ammonites and belemnites, which are so characteristic of the period preceding the cretaceous, in like manner die with it.

But, amongst these fading remainders of a previous state of things, are some very modern forms of life, looking like Yankee pedlars among a tribe of Red Indians. Crocodiles of modern type appear; bony fishes, many of them very similar to existing species, almost supplant the forms of fish which predominate in more ancient seas; and many kinds of living

[29] Pterodactyl. An extinct flying reptile. The spread of the wings varied from 3 to 15 feet.

[30] Ichthyosaurus. An extinct marine reptile, from 10 to 30 feet long.

[31] Plesiosaurus. An extinct marine reptile, with a long neck and small head. The length varied from about 9 to 18 feet.

shell-fish first become known to us in the chalk. The vegetation acquires a modern aspect. A few living animals are not even distinguishable as species, from those which existed at that remote epoch. The *Globigerina* of the present day, for example, is not different specifically from that of the chalk; and the same may be said of many other *Foraminifera.* I think it probable that critical and unprejudiced examination will show that more than one species of much higher animals have had a similar longevity; but the only example which I can at present give confidently is the snake's-head lamp-shell (*Terebratulina caput serpentis*), which lives in our English seas and abounded (as *Terebratulina striata* of authors) in the chalk.

The longest line of human ancestry must hide its diminished head before the pedigree of this insignificant shell-fish. We Englishmen are proud to have an ancestor who was present at the Battle of Hastings. The ancestors of *Terebratulina caput serpentis* may have been present at a battle of *Ichthyosauria* in that part of the sea which, when the chalk was forming, flowed over the site of Hastings. While all around has changed, this *Terebratulina* has peacefully propagated its species from generation to generation, and stands to this day, as a living testimony to the continuity of the present with the past history of the globe.

10. CAUSES OF CHANGES IN THE EARTH'S SURFACE

Up to this moment I have stated, so far as I know, nothing but well-authenticated facts, and the immediate conclusions which they force upon the mind. But the mind is so constituted that it does not willingly rest in facts and immediate causes, but seeks always after a knowledge of the remoter links in the chain of causation.

Taking the many changes of any given spot of the earth's sur-

face, from sea to land and from land to sea, as an established fact, we cannot refrain from asking ourselves how these changes have occurred. And when we have explained them—as they must be explained—by the alternate slow movements of elevation and depression which have affected the crust of the earth, we go still further back, and ask, Why these movements?

I am not certain that any one can give you a satisfactory answer to that question. Assuredly I cannot. All that can be said, for certain, is, that such movements are part of the ordinary course of nature, inasmuch as they are going on at the present time. Direct proof may be given, that some parts of the land of the northern hemisphere are at this moment insensibly rising and others insensibly sinking; and there is indirect, but perfectly satisfactory, proof, that an enormous area now covered by the Pacific has been deepened thousands of feet, since the present inhabitants of that sea came into existence. Thus there is not a shadow of a reason for believing that the physical changes of the globe, in past times, have been effected by other than natural causes. Is there any more reason for believing that the concomitant modifications in the forms of the living inhabitants of the globe have been brought about in other ways?

Before attempting to answer this question, let us try to form a distinct mental picture of what has happened in some special case. The crocodiles are animals which, as a group, have a very vast antiquity. They abounded ages before the chalk was deposited; they throng the rivers in warm climates, at the present day. There is a difference in the form of the joints of the back-bone, and in some minor particulars, between the crocodiles of the present epoch and those which lived before the chalk; but, in the cretaceous epoch, as I have already mentioned, the crocodiles had assumed the modern

type of structure. Notwithstanding this, the crocodiles of the chalk are not identically the same as those which lived in the times called "older tertiary," which succeeded the cretaceous epoch; and the crocodiles of the older tertiaries are not identical with those of the newer tertiaries, nor are these identical with existing forms. I leave open the question whether particular species may have lived on from epoch to epoch. But each epoch has had its peculiar crocodiles; though all, since the chalk, have belonged to the modern type, and differ simply in their proportions, and in such structural particulars as are discernible only to trained eyes.

How is the existence of this long succession of different species of crocodiles to be accounted for? Only two suppositions seem to be open to us— Either each species of crocodile has been specially created, or it has arisen out of some pre-existing form by the operation of natural causes. Choose your hypothesis; I have chosen mine. I can find no warranty for believing in the distinct creation of a score of successive species of crocodiles in the course of countless ages of time. Science gives no countenance to such a wild fancy; nor can even the perverse ingenuity of a commentator pretend to discover this sense, in the simple words in which the writer of Genesis records the proceedings of the fifth and sixth days of the Creation.

On the other hand, I see no good reason for doubting the necessary alternative, that all these varied species have been evolved from pre-existing crocodilian forms, by the operation of causes as completely a part of the common order of nature as those which have effected the changes of the inorganic world. Few will venture to affirm that the reasoning which applies to crocodiles loses its force among other animals, or among plants. If one series of species has come into exist-

ence by the operation of natural causes, it seems folly to deny that all may have arisen in the same way.

II. CHALK, THE NATURAL PRODUCT OF GREAT FORCES

A small beginning has led us to a great ending. If I were to put the bit of chalk with which we started into the hot but obscure flame of burning hydrogen, it would presently shine like the sun. It seems to me that this physical metamorphosis is no false image of what has been the result of our subjecting it to a jet of fervent, though nowise brilliant, thought tonight. It has become luminous, and its clear rays, penetrating the abyss of the remote past, have brought within our ken some stages of the evolution of the earth. And in the shifting "without haste, but without rest" of the land and sea, as in the endless variation of the forms assumed by living beings, we have observed nothing but the natural product of the forces originally possessed by the substance of the universe.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The Chalk-Beds of England and of Other Lands

1 How extensive are the chalk formations of the earth?
2 What is the purpose of the first five paragraphs?

2 The Chemical Nature of Chalk

3 What attitude toward science does Mr. Huxley wish his readers to take?
4 How important are the records of nature?
5 What is chalk from the point of view of chemistry?

3 Chalk Under the Microscope

6 How does chalk differ from other lime formations?
7 Give directions for interesting experiments with chalk.
8 Explain the composition of chalk.

4 Living Makers of Chalk

9 Is chalk being formed today?
10 Tell about Lieutenant Brooke's investigation of the bottom of the sea.
11 How did practical necessity lead to scientific study of the bottom of the sea?
12 How are the discoveries concerning the bottom of the sea related to the study of chalk?

5 Chalk, the Mud of an Ancient Sea

13 Explain the steps by which scientists learned the cause of chalk formations.

6 Proofs of the Method of Chalk Deposit

14 How do we know that chalk was formed at the bottom of the sea?

7 The Slowness of Chalk Deposit

15 How long a time was required for the formation of the present chalk-beds?
16 Explain how scientists learned the length of time required for the formation of chalk-beds.

8 The Date of Chalk Deposits

17 How did investigators learn who were the ancient inhabitants of Europe?
18 What did investigators learn about the lives of ancient Europeans?
19 How ancient is chalk as compared with man?
20 By what means did men learn what happened after the formation of the chalk deposits?
21 Suggest a series of moving pictures to represent the history of the making of the land that we now call "England".

9 Changes Indicated by Chalk

22 What proves that "Chalk is older than the hills"?
23 How did the world at the time of the formation of the chalk-beds differ from the world of today?
24 What do the chalk-beds reveal concerning past life?
25 How ancient are some of the present forms of life?

10 Causes of Changes in the Earth's Surface

26 What do scientists strive to learn, in addition to bare facts?
27 What changes in the surface of the earth are now being made?

11 Chalk, the Natural Product of Great Forces

28 Why does the figure of speech in the closing paragraph add force to the paragraph, and to the entire essay?
29 Summarize the thought of the entire essay.
30 How does Mr. Huxley make his thought clear?
31 What spirit does Mr. Huxley show throughout the entire work?
32 What makes the essay interesting?
33 Write a short essay on one of the following topics:
(a) Indian Arrow Heads.
(b) What I Saw in the Woods.
(c) The History of a River.
(d) The Side of a Hill.
(e) A Great Tree.

BOOKS FOR FURTHER READING

Lay Sermons, Thomas H. Huxley, *Dutton,* 1910.
Marvels of Geology, E. S. Grew, *Lippincott,* 1919.
The Romance of Geology, Enos Abijah Mills, *Doubleday,* 1926.
The Story of Geology, Allan L. Benson, *Cosmopolitan Book Corporation,* 1927.
Geology, Arthur R. Dwerryhouse, *Stokes,* 1917.
The Story of the Earth, O. W. Washburn, *Century,* 1916.
The Story of Ab, the Cave Man, Stanley Waterloo, *Doubleday,* 1918.
Men of the Old Stone Age, Henry F. Osborn, *Scribner,* 1918.
Evolution, Vernon Kellogg, *Appleton,* 1924.

CHEMISTRY IN EVERYDAY LIFE

By

EDWIN EMERY SLOSSON

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"Whether it be the satisfaction of our material wants or the gratification of our aspirations for art and literature, the chemist acts as the agent of applied democracy."

EDWIN E. SLOSSON.

EDWIN EMERY SLOSSON
(1865-)

Dr. Edwin E. Slosson has the distinction of having written a book of science, *Creative Chemistry,* that became a "Best Seller." He has the gift of writing in a way that at once interests and instructs. He is especially fortunate in being able to write about technical subjects with remarkable clearness, with unusual power of explanation, and even with the saving grace of wit and humor.

For some time Dr. Slosson taught chemistry, and worked as a chemical expert. From 1903 to 1920 he was Literary Editor of *The Independent.* At about the same time, from 1912 to 1920, he taught in the Columbia University School of Journalism. Later he became Director of Science Service, Washington, D. C.

Among Dr. Slosson's books are the following: *Great American Universities* (1910); *Major Prophets of Today* (1914); *Six Major Prophets* (1917); *Creative Chemistry* (1919); *Easy Lessons in Einstein* (1920); *The American Spirit in Education* (1921); *Plots and Personalities* (1922); *Chats on Science* (1923); *Sermons of a Chemist* (1925), and *Snapshots of Science* (1928).

CHEMISTRY IN EVERYDAY LIFE

By Edwin Emery Slosson, Ph.D.

I. VALUES CONTRIBUTED BY CHEMISTRY

IT TOOK the Great War to rouse the public to the power and importance of chemistry. It was a war of chemists against chemists—in the making of nitrate explosives and diabolical poison gases. Afterwards the chemists of all countries turned with relief to the more congenial task of contributing to national health and prosperity.

Nitrogen, perverted by militarism to destruction, was meant by the chemist for creation. A ton of wheat takes away from the soil about forty-seven pounds of nitrogen, eighteen pounds of phosphoric acid, and twelve pounds of potassium. Therefore, if the farmer does not restore this much to his soil every year he is drawing upon his capital.

Before the war the European farmer was constantly feeding his capital through importations of nitrate fertilizer from the rich beds of western South America. The German yield in bushels of wheat per acre was nineteen in 1889-90. In 1913 it was thirty-five. In the United States the figures were twelve and fifteen. Germany imported 55,000 tons of Chilean saltpeter (sodium nitrate) in 1880 as against one hundred and thirteen bushels for the United States. But the United States uses only twenty-eight pounds of fertilizer per acre, while Europe uses two hundred. For three hundred years American farmers have been living on the unearned increment of the unoccupied land. This is more *mining* than agriculture. Now

we must consider conserving our capital. Uncle Sam is exceptionally lucky in his inherited wealth, but he has not been idle in improving his property. From corn he has learned how to prepare a hundred useful products, from salad oil on our tables to the "rubber" tips on our pencils.

He has added ten dollars to the value of every bale of cotton by extracting oil from seed that used to be thrown away. He wastes nothing of the hog but the squeal, and he is now saving the smoke from his coke ovens. Out of this—the smoke, not the squeal—he gets ammonia and coal tar, and from tar in turn are produced the thousands of dyes and drugs and other chemicals that have become essentials of our civilization. Before the war, Germany had gained control of the coal-tar products, and all other countries paid her tribute. But they were forced into dependence during the war, and the German monopoly was shaken. Before 1914, the United States used some $15,000,000 worth of coal-tar colors, and over $10,000,000 of these were *imported*. Then the tide turned, and in 1920 the United States made enough dyes for her own use and *exported* $33,000,000.

2. WHAT COAL GIVES US

If you want to find out for yourself what coal contains, put a bit into a test tube and heat it. When the gas burns off, there will be, at the bottom of the tube, a piece of dry, porous coke. But in the middle of the tube, where it is neither too hot nor too cold, there will be water and some black sticky stuff. This tar was formerly considered a clogging nuisance and was thrown away. But chemistry has discovered that it is one of the most useful things in the world. It is one of the strategic factors in war and commerce. It wounds and heals. It is the basis of munitions and medicines. Into the black mass

the chemist thrusts his hand and draws out all the colors of Joseph's coat.

Coal tar supplies all sorts of useful materials because it is the quintescence of the forests of untold millenniums. It is the scrap heap of the vegetable kingdom. It contains a little of almost everything that makes up trees. From the dozen primary products extracted from coal tar the chemist builds up hundreds of thousands of new substances, most of them not to be found in plants, and never even having had existence before being made up in the laboratory. Any kind of dye found in nature, whenever its composition is understood, can be made in the laboratory—and usually it can be made cheaper and purer than it can be extracted from the plant.

Before man found that he could make up all the dyes he wanted from the tar he had been burning up at home, he was searching the world over to find colors. For the Tyrian purple, which was formerly the insignia of royalty, he sought out a snail-like shellfish of the eastern coast of the Mediterranean, and from a tiny sack behind its head extracted a drop of thick whitish liquid smelling like garlic. For scarlet he robbed the lady cochineal bug of her coat. For indigo he went to India. A hundred years ago indigo cost as much as four dollars a pound. In 1914 we were paying fifteen cents a pound for it. Even the pauper labor of India could not compete with chemistry.

All the coal-tar products are so interrelated that the same factory and much the same processes may be employed in war and peace. In fact, in some cases, identically the same compound plays many parts. For instance, the yellow powder known as picric acid is a dye and an explosive. A soldier fighting under a yellow flag dyed with picric acid might have been wounded by a shell filled with picric acid and taken to a

hospital where his wound was disinfected with picric acid. The armistice left us with a large supply of poisonous chemicals on hand, which, fortunately, were no longer needed, and which we hope will not be needed in the future. Many of these have been transformed by simple processes into dyes and drugs and perfumes. Phosgene, one of the most dreaded of the poison gases, is now being transformed into *violet perfume* by the addition of a preparation from castor oil.

It was in Philadelphia that the first chemical society was founded in 1792. And here Robert Hare [1] invented the oxy-hydrogen blowpipe and set up the first electric furnace. To-day the American Chemical Society, with 16,750 members, is the largest special scientific society in the world, and Niagara Falls is the greatest center of electro-chemical industries in the world. Among their products is aluminum, which Hall,[2] an Oberlin student, discovered how to extract by the electric current. The same electric agency separates common salt from the metal sodium and the gas chlorine, the former giving us lye for soap making, and the latter serving as a still more active detergent [3] and disinfectant.

But electricity can unite as well as divide, and the power of Niagara Falls brings out of coal and sand a new substance, Acheson's [4] carborundum, harder than anything in nature except the diamond, and capable of cutting away the toughest steel. If the electric current is passed through a mixture of coal and lime, we get calcium carbide, which serves as the starting point for many useful products. Drop the carbide into water,

[1] Robert Hare (1781-1858). Professor of Chemistry in the University of Pennsylvania.

[2] Charles Martin Hall (1863-1914). An American inventor, awarded the Perkin Medal for Chemistry in 1911.

[3] Detergent. A cleanser.

[4] Edward Goodrich Acheson (1856-). An American electrician, the inventor of carborundum.

and acetylene gas comes bubbling up. This, combining with oxygen from the air, gives a light bright enough to illuminate the path of the automobile or a heat sufficient to cut curves in a boiler plate as easily as the old-fashioned bracket-saw carved up hollywood. Hot carbide absorbs the nitrogen from a stream of air passed over it, and the compound so formed, when treated with steam, gives ammonia, which in turn can be made over into nitric acid—or a stream of artificial lightning passed through air will produce nitric acid directly. Nitric acid acting on cotton makes nitro-cellulose, used for smokeless powder. All the explosives, high and low, are made from nitric acid, so it was only the discovery of methods of getting the free nitrogen of the air into combination that enabled the Great War to be fought to a finish.

3. CELLULOID AND RUBBER

But nitro-cellulose has its peaceful pursuits as well as its war aims. A journeyman printer named Hyatt[5] discovered, on combining it with camphor, that he got something new that he named "celluloid." This compound is capable of passing itself off as ivory or amber, or, undisguised, serving as the backing for photographic films. Designed for the purpose of imitation, it is in many ways better than the materials it imitates. Tortoise shell, for example, cracks, splits, and twists, but a "tortoise shell" comb of celluloid looks as good and lasts longer. Horn articles of real horn are naturally limited as to size, but an imitation of horn can be made of any thickness by wrapping celluloid sheets about a cone. Ivory may be imitated by rolling together alternate white opaque and col-

[5] John Wesley Hyatt (1837-1920). An American inventor, noted for the invention of celluloid, a lock-stitch sewing machine, and a method of purifying water.

orless translucent sheets. Some of the sheets are wrinkled in order to produce the knots and irregularities of the grain of natural ivory. Red coral can be perfectly imitated by taking a cast of a coral branch and filling in the mold with celluloid of the same color and hardness. The clear luster of amber, the dead black of ebony, the cloudiness of onyx, the opalescence of alabaster, the glow of carnelian, are now within the reach of everyone, thanks to this chameleon material.

To a Belgian chemist, Baekeland,[6] we owe "gaslight" photographic paper, also a synthetic plastic made from carbolic acid and formalin, named from its inventor "Bakelite." It is used largely as an insulator in electrical apparatus in place of hard rubber.

This reminds us that rubber dates back to that lucky accident of 1839, when Goodyear,[7] a persistent Yankee genius, dropped a mixture of *caoutchouc* and sulphur on his kitchen stove and found when he picked it up that he had a tough and elastic material quite unlike the tacky gum and the yellow powder. To-day three quarters of all the rubber in the world is worked up in the United States—enough to "tire" the entire earth.

Scientifically, the problem of synthetic rubber has been solved; but not industrially. It can be made, but it cannot yet be made to pay. The difficulty is to find a cheap enough material to start with. We can make rubber out of potatoes—but potatoes have other uses. It would require more land, and more valuable land, to raise the potatoes than to raise the rubber. But eventually man will overcome that difficulty,

[6] Leo Hendrik Baekeland (1863-). A Belgian-American chemist, awarded the Nichols' Medal, and the J. Willard Gibbs' Medal of the American Chemical Society.

[7] Charles Goodyear (1800-1860). An American manufacturer. In 1844 he patented the method of vulcanizing rubber.

and then, no matter how much synthetic rubber may be manufactured, there will be no danger of glutting the market, for as the price falls the uses of rubber will become more numerous. One can think of a thousand ways in which rubber could be used if it were only cheap enough. There is hardly any other material whose abundance would contribute more to our comfort and convenience.

4. SUGAR, FOOD, AND FUEL

Once sugar came only from the cane. Then a chemist discovered that it was possible to extract sugar from the beet. At first there was only a little sugar in the beet root—some six per cent, and that was dirty and bitter. In 1810 Napoleon offered a prize of a million francs for a practical process of extraction. By selection the percentage of sugar from the beet rose from six to eighteen per cent and, by improved methods, became as pure and palatable as the sugar of the cane. As soon as the chemist made it possible to produce sugar at a reasonable price, all the nations began to buy it in proportion to their means. Americans, as the wealthiest people in the world, eat the most—over one hundred pounds a year on the average for every man, woman, and child. Pure white sugar is the first and greatest contribution of chemistry to the world's dietary.

Food in the body and fuel in the engine serve substantially the same purpose. They provide the energy for work. The carbohydrates—that is, the sugars, starches, and celluloses —can all be used as fuels, and by some animals as foods. The final products, water and carbon dioxide, are in both cases the same, and necessarily, therefore, the amount of energy produced is the same in the body as in the engine. Corn is a good sample of the equivalence of the two sources of en-

ergy. There are few better foods and no better fuel. In the old days, when corn was generally burned in the Western States, it was both an economy and a luxury, for, at ten cents a bushel, it was cheaper than coal or wood and preferable to either at any price. The long yellow ears, each wrapped in its own kindling, could be handled without crocking the fingers. Each kernel as it crackled sent out a blazing jet of oil, and the cobs left a fine bed of coals for the corn popper to be shaken over. Driftwood and the pyrotechnic fuel they now make by soaking sticks in strontium and copper salts cannot compare with the old-fashioned corn-fed fire in beauty and heat-giving.

5. BY-PRODUCTS OF COTTON

Old is the cry, "Cotton is King." But two thirds of the cotton crop, the seed, was wasted until the chemist found a practical use for it. He has added $295,000,000 a year to the value of the United States cotton crop by discovering ways of utilizing the cotton seed that used to be thrown away or used as fuel. The fuzz of cotton fiber sticking to the cotton seed can be removed by machinery and used for any purpose where length of fiber is not essential. For example, it can be nitrated and used for making smokeless powder or celluloid. The hulls of the cotton seed, amounting to seven hundred or nine hundred pounds in a ton, were formerly burned. Now they bring about twelve dollars a ton, and are ground up into cattle feed or paper stock or used as fertilizer. On being pressed, the kernel of the cotton seed yields a yellow oil and leaves a mealy cake. This last, mixed with the hulls, makes a good fodder for fattening cattle. Cotton-seed meal contains about forty per cent of protein, and is therefore a highly concentrated and very valuable feeding stuff. Even more valuable is the oil from the cotton seed. The seed con-

tains about twenty per cent of oil, most of which can be squeezed out of the hot seeds by hydraulic pressure. The eventual refined product is a yellow oil, suitable for table use. Once it masqueraded as olive oil. Now it competes in the open, and America annually ships some 600,000 pounds of it to the Mediterranean.

6. IRON, THE AFFINITY SEEKER

Iron is one of the most timid of metals. It dislikes to be alone, prefers almost every other element to itself, and has an especial affection for oxygen. As oxygen is in both air and water, iron is not long without a mate. The result of this union is, in common language, iron rust. One of man's greatest triumphs was the discovery of undoing iron rust and getting metal out of it.

The prosperity of modern states is dependent on the amount of iron rust which they possess and utilize. Nations are competing to see which can dig the most iron rust out of the ground and convert it into railways, bridges, buildings, machinery, and battleships, and then let them relapse into rust again. Civilization can be measured by the amount of iron rusted per capita, or, better, by the amount rescued from rust.

It is because iron is so rustable that it is so useful. The factories with big scrap heaps of rusting machinery are making the most money. The united elements, known to the chemist as iron oxide, and to the world in general as rust, are among the commonest of compounds, and their colors, yellow and red, are displayed on every mountainside. Man has been laboring ceaselessly to divorce these elements, and, having separated them, to keep them apart so that the iron may be retained in his service. Every year the blast furnaces of the world release 86,000,000 tons of iron from its oxides, and every year a

large part reverts to its primeval forms. Thus after centuries of effort man has barely got a few years ahead of nature, and if he were to stop for a generation there would be little left to show that he had ever learned to extract iron from its ores. To save a pound of iron from corrosion is as much benefit to the world as to produce another pound from the ore. In fact, it is of much greater benefit, for it takes four pounds of coal to produce one pound of steel, so that whenever a piece of iron is allowed to oxidize it means that four times as much coal must be oxidized in order to replace it. And the coal beds of the world will be exhausted before the beds of iron ore. It is the eternal struggle of man against nature.

The value of iron lies in its versatility. It is a dozen metals in one. It can be made hard or soft, brittle or malleable, tough or weak, resistant or flexible, elastic or pliant, magnetic or non-magnetic, more or less conductive to electricity, by slight changes of composition and differences of treatment. The medieval mind ascribed these mysterious transformations to witchcraft. But modern science studies it in the light of its component minerals. With this knowledge at his disposal the iron maker can work with his eyes open and so regulate his melt as to cause these various constituents to crystallize out as he wants them to. He is no longer confined to the alloys of iron and carbon. He has found new elements to add to his alloys, some of them possessing great practical value. Vanadium, for instance, was formerly confined to the attention of the advanced student of chemistry. To-day it is known to everyone who runs a motor car. Tungsten has become familiar through the tungsten lamps. The public is now learning to spell mo-lyb-de-num. Upon the presence and proportions of such ingredients as vanadium, tungsten, chromium, titanium,

nickel, cobalt, phosphorus, molybdenum, silicon, and sulphur depends the quality of steel, and a variation of a tenth of a per cent in certain of them will make a different metal out of it.

When platinum was first discovered it was so cheap that ingots of it were gilded and sold as "gold bricks" to unwary purchasers. The "gold brick" scheme would now have to be reversed, for gold is used, as a cheaper metal, to "adulterate" platinum. Formerly, the Russian Government used platinum as we use nickel, for making small coins. But it is really a rare metal, found nowhere in quantity save in the Urals, and, since it seems indispensable in chemical and electrical appliances, the price has continually gone up. Just when the demand for platinum for war purposes was the heaviest Russia collapsed, and the other governments had to put a stop to its use for jewelry and photography. All the members of the platinum family, formerly ignored, were pressed into service —palladium, rhodium, osmium, iridium—and these, alloyed with gold or silver, were employed more or less satisfactorily by the dentist, chemist, and electrician as substitutes for the platinum of which they had been deprived. It is a pity that this family of noble metals is so restricted, for they are unsurpassed in tenacity and incorruptibility.

7. CHEMISTRY AS THE DEMOCRATIC SCIENCE

Chemistry is a most effectual agent for demoracy, since it actually accomplishes in regard to many material things that equality which legislation aims to bring about in the political sphere. Luxuries, formerly the monopoly of the privileged classes, become, through applied science, the common property of the masses. The "royal purple" of the ancients, and dyes far more beautiful are now to be had on the bargain

counter, and Solomon [8] in all his glory was not arrayed like the modern American maiden. Even though her purse be scant, she need not lack jewels and bright raiment such as once were worth a slave's life. Fruits exotic and out of season are upon our dinner table, and the china we eat them from is not brought from China, but made from a clay bank at home. In early ages the man who owned a piece of steel shaped it into a sword and made himself master of his fellows. Now we make buildings out of steel, and he who lives in the garret of one of them could look down on the tower of Babel.[9] The Feudal Age vanished at the first whiff of gunpowder, for that device of the black art leveled the natural and the artificial inequalities of humanity in warfare, since with a gun in his hand the churl could meet the knight on equal footing and the dwarf was match for the giant—more than a match, for the dwarf had the larger target.

Medicines such as a prince could not have procured, though his physicians surveyed the earth from China to Peru, are now at hand to cure the pauper. The new chemical motive powers have given man in the automobile a very fair substitute for the seven-league boots of the fairy tale; they enable him to go down into the sea in ships on more or less lawful occasions, and they have endowed him with the wings that he has always longed for but never expected to get until he reached heaven. Books are no longer chained up in treasuries, but, manifolded by the magic of ink, are to be bought on the street corner like peanuts; pictures from the private gallery of prince or plutocrat are multiplied by the same mechanism

[8] Solomon (993-953 B.C.). King of Israel. "Consider the lilies of the field. Even Solomon in all his glory was not arrayed like one of these." Matthew, 7: 28, 29.

[9] Tower of Babel. "Let us build us a city and a tower, whose top may reach unto heaven." Genesis, 2:4.

and scattered throughout the land. We do not have to pay ten dollars to hear a song by Galli-Curci,[10] since we can hear her at home. Caruso,[11] though dead, yet speaketh. Events that few could witness are brought to all of us on the celluloid film. So, whether it be the satisfaction of our material wants or the gratification of our aspirations for art and literature, the chemist acts as the agent of applied democracy.

Nor has the chemist exhausted the possibilities of his science; there are greater marvels in sight. In the radio-active elements, such as radium, we have come upon sources of an energy that was never dreamed of by man. The most striking peculiarity of radium is that it is always a little warmer than its surroundings, no matter how warm these may be. It decomposes, and we know no way of hastening or of checking it. An ounce of radium salt will give out enough heat in one hour to melt an ounce of ice, and in the next hour will raise this water to the boiling point, and so on again and again for years, a fire without fuel. From the heavy white salt there is continually rising a faint fire-mist. This gas is known as radon, "the shining one." A pound of radon would give off energy at the rate of 23,000 horsepower; fine stuff to run a steamer, one would think—but it does not last. By the sixth day the power would have fallen off by half. Besides, no one would dare act as engineer, for the radiation will rot away the flesh of a living man who comes near it. It will not only break down the complex and delicate molecules of organic matter, but also will attack the atom itself, changing one element into another, the fulfilment of a dream of the alchemists!

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[10] Amelita Galli-Curci (1889-). An Italian-Spanish coloratura soprano.

[11] Enrico Caruso (1873-1921). A great Italian singer.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 Values Contributed by Chemistry

1 How does chemistry help agriculture?
2 How does chemistry make use of what once was called "waste"?
3 What does chemistry do for the United States?

2 What Coal Gives Us

4 Why is coal tar valuable?
5 What changes does chemistry bring about?
6 Explain some of the remarkable, and apparently contradictory, uses of certain chemicals.
7 To what extent has chemistry developed in the United States?
8 Tell about some of the remarkable products that chemistry is now producing.
9 How did chemistry aid in the Word War?

3 Celluloid and Rubber

10 What are some of the products of nitro-cellulose?
11 Tell about some of the common, useful products now made by chemistry.
12 What advantages is chemistry likely to give us in the future?

4 Sugar, Food, and Fuel

13 Explain the relation between food and fuel.
14 What has the chemist to do with the production of food?

5 By-Products of Cotton

15 What values are found in cotton seed?

6 Iron, the Affinity Seeker

16 By what means does Dr. Slosson make his paragraphs about iron interesting?
17 What characteristics make iron valuable?
18 Explain the change in the valuation of platinum.

7 Chemistry as the Democratic Science

19 How does chemistry aid democracy?
20 Explain the wonders of radium.

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CHLORIN

By

JEAN-HENRI FABRE

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"Air, nitrogen, oxygen, hydrogen, carbonic-acid gas, and carbon monoxide are gases that not even the sharpest eyes can see; and most other gases are of like character in this respect, so that gases as a class are thought of by us as invisible. Now, however, we have a gas that is as subtle and impalpable as the others and yet can be seen very well."

J. H. FABRE.

JEAN-HENRI FABRE
(1823-1915)

The French entomologist, Jean-Henri Fabre, studied nature so long, recorded so many observations, and so appealed to the hearts of people, that he made himself much loved. His clear, simple notes so express his charming personality and the spirit of nature that he is well called "The Poet of Science." J. Henri Fabre was both observer and revealer.

In youth M. Fabre turned from the classics, and gave himself to mathematics and science. He taught at Avignon, and was Professor of Physics at Ajaccio. While he showed interest in astronomy, botany, chemistry, physics and zoölogy, he delighted most in entomology. He made valuable discoveries concerning bees, wasps, and beetles.

M. Fabre's charming books, his interest in children, the tragedy of the death of his brilliant son, and the fact that he lived to the age of 92, combined to awaken interest in him and in his work.

He published his observations in *Annales des Sciences Naturelles* (1855-8), and in *Souvenirs Entomologiques* (1879-1907). From those works, and from other sources, much of his work has been translated into English. Among the English titles are the following, arranged in order of translation: *Insect Life; Life and Love of the Insects; Social Life in the Insect World; Life of the Spider; Life of the Fly; Mason Bees; Bramble Bees and Others; Hunting Wasps; Insect Adventures; Life of the Grasshopper; The Story Book of Science; Our Humble Helpers; The Sacred Beetle and Others; The Wonders of Instinct; Field, Forest and Farm; Mason Wasps; The Secret of Everyday Things; More Hunting Wasps; Animal Life in Field and Garden; Life of the Weevil; The Wonder Book of Chemistry; More Beetles; Life of the Scorpion; The Heavens; Here and There in Popular Science; Curiosities of Science.*

CHLORIN

By Jean-Henri Fabre

I. AN EXPERIMENT WITH TABLE SALT

WE HAVE more than once had occasion to speak of salt, common cooking-salt, and I have told you that it is composed of sodium and chlorin, a metal and a metalloid. In the language of chemistry, salt is chlorid of sodium."

"Are you going to show us some sodium and let us see what it looks like?" asked Emile, his curiosity aroused by the little he had already heard about this metal.

"No, my young friend. Sodium, though not so very rare in drug stores, is too expensive a luxury for our little village laboratory; and so we must content ourselves with a mere description of it. Imagine something that shines like freshly cut lead, and so soft as to yield to the pressure of one's fingers. In fact, it can be molded like wax. Put a piece of it on water and, floating there, it will catch fire and spin around all wrapped in flames. Potassium, the metal contained in ashes, does the same, only more violently. We are now in a position to understand why these two metals have this strange peculiarity of catching fire as soon as they come into contact with water.

"What is water really made of? Oxygen and hydrogen. Ever since our visit to the blacksmith's shop we have known that red-hot iron decomposes water, appropriating its oxygen and releasing its hydrogen. Unheated iron and also zinc will decompose water in the same way, with no use whatever of

fire, if sulphuric acid is added to assist the process. Well, potassium and sodium, as well as some other substances, notably the metal of lime, or calcium, are more active than iron and zinc in the presence of water. Left to play their part unassisted, without heat and without the help of sulphuric acid or anything else, they decompose the water, take to themselves its oxygen, thus becoming oxids, and release the hydrogen. Now, it is this uniting of the oxygen with the metal, this combustion, that develops heat sufficient to set the freed hydrogen on fire; and that explains the flames enwrapping the metal as it spins around on the surface of the water. When the flames die down, the potassium or sodium has disappeared, without leaving the slightest visible trace behind; but the water in which the oxid of the metal was dissolved has now a burning taste and an odor of lye; moreover, it will restore the blue color to litmus previously turned red by an acid.

"If I have no sodium to show you, I can at least let you see the element with which it is joined in partnership in our common salt: I can show you chlorin, which is of more importance than sodium. To obtain chlorin from salt, use is made of sulphuric acid, that powerful agent employed in so many operations in the domain of chemistry. In the present instance the acid's part is to appropriate the metal and thus set the chlorin free. But in order to combine with the acid, the sodium must first be converted into an oxid, into soda; and for this, oxygen is required. The duty of supplying this oxygen is assigned to dioxid of manganese, that same black powder we used in obtaining oxygen from a salt. Its function then was to regulate the heat throughout the mass of salt and thus make easier the decomposition of the latter. Now, however, its purpose is quite different: itself very rich in oxygen, its office is to give up some of this to the sodium, which will

thus become soda; and this in turn will then combine with the sulphuric acid to form sulphate of soda. These combinations being effected, the chlorin will be left in a free state, no longer fettered by the bonds hitherto uniting it with the metal sodium.

"The apparatus for this operation is the same as that used in obtaining oxygen. Into our glass balloon I put a handful of common salt and the same amount of dioxide of manganese. I mix them well and sprinkle freely with sulphuric acid. Then, with its tube attached, the balloon is set in place over the brazier so as to receive the heat from the few live coals the brazier contains. A very gentle heat is enough, the release of chlorin beginning even before the temperature has risen at all. Chlorin is a gas heavier than air, and so we will collect it as we collected our carbonic-acid gas; that is, we will arrange the tube from the balloon in such a manner that it will reach to the bottom of our wide-mouthed bottle or jar in which we propose to store the chlorin.

"Up to this point we have had to do only with invisible gases. Air, nitrogen, oxygen, hydrogen, carbonic-acid gas, and carbon monoxid are gases that not even the sharpest eyes can see; and most other gases are of like character in this respect, so that gases as a class are thought of by us as invisible. Now, however, we have a gas that is as subtle and impalpable as the others and yet can be seen very well. It owes its visibility to its pale greenish-yellow tinge. Its name, chlorin, which comes from a Greek word meaning *green,* takes note of this quality.

"Because of this slight color possessed by chlorin we can watch the gas as it accumulates in the bottom of the jar, where it is held by its weight, and where, also, it displaces the air previously occupying the same space but now driven out by reason of its lesser weight. See there! In the bottom of the

jar there appears a kind of fine yellowish vapor, the layer increasing in thickness little by little and filling more and more of the jar from the bottom upward. That yellowish vapor is chlorin; what is above it, colorless and invisible, is air. Wait a few minutes and the visible layer will reach the neck; the jar will then be full of chlorin."

As soon as it was full, the jar was covered with a piece of glass and a second jar filled in the same manner. But during the operation a little of the gas had escaped into the room, perhaps allowed to do so by Uncle Paul [1] in order to teach his pupils how disagreeable chlorin is to breathe. Emile in particular learned the lesson so as never to forget it. Happening to be near the apparatus just when the empty jar was substituted for the full one, he received a whiff of the offensive gas in his nostrils, whereupon he was seized with a fit of coughing such as no cold or whooping-cough had ever caused him. And so our giddy-pate coughed and spat and spat and coughed, but all in vain, in his effort to get rid of what was choking him. It needed his uncle's reassurance to calm his fears as to the consequences of this accident.

"It is nothing, my young friend; you'll get over your coughing in a few minutes. It was the chlorin that started it, but luckily only a very little of it reached you, and that little was mixed with a good deal of air, so that you smelt the terrible gas more than you swallowed it. Drink a glass of cold water, and that will help to clear your throat."

The cough did in fact soon subside, and the misadventure

[1] "Uncle Paul," who tells the story, is, of course, the author himself, Jean-Henri Fabre. "Jules" and "Emile" are his own two sons, drawn as close to life as the author could draw them. The names are the real names of the two boys. The older boy, Jules, a lad of great scientific promise, died at the age of 15.

had no other consequence than to make its victim rather more cautious thereafter about venturing near the jars of chlorin.

"Now you are over-cautious, my child," said his uncle. "A slight smell of chlorin is nothing to be afraid of; it may even be rather wholesome, especially when the air is foul with the products of decay. What is to be feared is breathing this gas pure and admitting it into the lungs in some considerable quantity. Whoever should fill his chest with it, as we fill our chests with atmospheric air, would die in fearful agony after a few breaths."

"I should think as much," declared Emile, "after the fit of coughing I got from just a whiff of it. But how queer it is that common salt should be made of chlorin that suffocates us and sodium that would burn out our mouths if we took the least bite of it! It's lucky those two fearful substances change so much when they come together, or I should never again dare to salt a radish before eating it."

2. THE BLEACHING POWERS OF CHLORIN

"It is lucky, too," continued his uncle, "that as soon as it is separated from sodium, chlorin regains its energetic properties, for manufacturers profit greatly by these in certain branches of their industry. We will, however, confine ourselves to the one chief use that is made of chlorin, which is in bleaching. Into this jar filled with chlorin I pour some writing-ink from your inkstand there. I shake the jar to make the gas act on the liquid, and in a trice the thing is done. The ink, which was at first of a deep black, has turned to a pale yellow and now looks like slightly muddy water. The liquid so strongly colored at the start is left with hardly any color, the chlorin having destroyed the black of the ink.

"Another way to show the same thing will interest you even

more. Here is a sheet of paper written on with ordinary ink, a sheet taken from one of your old copy-books. I moisten it with water to hasten the chemical action of the gas, and put it into our second jar of chlorin. Is it not marvellous to see what now follows? The written characters fade away rapidly, and the paper is left as white as it ever was. I take the paper out of the jar so that you may examine it more closely. Look at it well and tell me whether you can see any trace of the writing that was on it."

The boys gave the sheet of paper the closest scrutiny, but could not distinguish a single letter. The paper looked as if it had never been used, and the utmost they could make out was an occasional scratch of the pen where it had pressed very hard.

"The writing has all disappeared," declared Jules, "and the paper is as good as new. Would sulphur gas do that? It turns violets and roses white."

"No, it would have no effect. Sulphur is too weak a bleacher. In many cases it is without effect, and here too it would be powerless. Chlorin, on the contrary, has so great a bleaching power that few dyestuffs can withstand it. In this respect it is the most useful agent known to the industrial arts. Nevertheless, not all colors fade away when subjected to the action of chlorin, as a third experiment will prove to you. I take a leaf of an old book of no value and write on it with ordinary ink, even smearing it with blots like a child that does not know how to handle a pen. When the ink is dry, I moisten the page a little and put it into the chlorin. My writing and my ink-blots vanish as by magic, but the print remains as black as ever. The page is now as clean as when first leaving the hands of the printer. The marks I made with writing-ink have been removed, but the printed words have lost nothing

of their clearness: they stand out very black against the white background of the paper. The ink-stained and illegible page has been so transformed by the chlorin that it now looks like a leaf from a new book."

"But why is it," asked Jules, "that the printing-ink stays as it was while the writing-ink is all bleached out?"

"That is because the two inks are made of different materials. Printers' ink is made of lampblack and linseed oil. Lampblack is a form of carbon and hence a simple substance, an element, and not something that can be decomposed. Now, chlorin acts on dyestuffs by decomposing them and then combining with one of their elements, hydrogen. Lampblack, which is carbon and nothing more, cannot be decomposed; it cannot give to the chlorin any hydrogen, because it has none to give; hence it remains lampblack and thus keeps its black color. Not so with writing-ink, however: that contains various ingredients, being usually made of sulphate of iron, gall-nuts, and logwood. The two latter belong to the vegetable kingdom and contain hydrogen, which the chlorin seizes; and, one of the elements being thus removed, the color disappears.

3. CHLORIN IN CLOTH-MAKING

"The principal use of chlorin as a bleacher is in the manufacture of woven fabrics and of paper. The perfect whiteness of our linen and our writing-paper we owe to chlorin; and so it comes about that before we can have any white paper for writing or printing, or any white cotton or linen for making shirts, handkerchiefs, curtains, and other articles, as well as for making gaily colored calico, we have to call in the services of salt,—or, rather, of that element in salt that we obtain with the help of sulphuric acid and then use as a bleaching agent. There you have an example, to add to the many other ex-

amples, of the important part sulphuric acid plays in our manufactures.

"The natural color of hemp and linen is a light reddish, and so fixed is it that it disappears only after repeated washings; hence, the longer a piece of linen has been used and the more times it has passed through the laundry, the whiter and softer it is. To give to linen the utmost possible whiteness, we spread it out on a closely mown meadow and leave it there for weeks at a time, exposed to the sunlight by day and to dampness by night. This prolonged exposure to sun and air, with alternate moistening and drying, finally weakens the hold of the reddish color so that subsequent washings gradually remove it entirely.

"But this method of bleaching is very slow, and when it is applied to great quantities of cloth and over long periods of time, it is also very costly, because it withholds a considerable area of land from productive use. Consequently, in factories where linen and hemp and especially cotton goods are made, a more powerful and less dilatory bleaching agent than sun and dew is called into service; and this agent is chlorin, whose speedy effect on ink you have just seen. Evidently a gas that can take out so black a color as that of ink, and do it so quickly, can easily remove the faint reddish tinge marring the whiteness of hemp, linen, and cotton."

"Wool and silk, too," suggested Jules, "could be bleached with chlorin, and that would be a much quicker way than with burning sulphur."

"But no one except a bungler would for a moment think of trying it," replied his uncle. "This gas would attack wool and silk and soon reduce them to a mere pulp."

"But you say cotton, linen, and hemp can stand it."

"Yes, but their resistance to the action of drugs has no parallel,—a fact that gives them inestimable value. Just think

of the many uses we make of linen and cotton and hemp fabrics, and what rough handling they receive,—repeated washing with corrosive lye and the strongest soap, rubbing and beating, and exposure to sun, air, and rain. What sort of material, then, is this that withstands the harsh treatment of washing with soap and of exposure to sun and weather, that remains intact even when all around it is decay, and that defies the manufacturers' powerful drugs and emerges from all these tests whiter and more supple than before? This almost indestructible material is the vegetable fiber of the plants known to us as hemp, flax, and cotton, a fiber unrivaled in its kind. Chlorin, which leaves textiles made of this fiber uninjured, while at the same time bleaching them to an exquisite whiteness, destroys all fabrics made of animal fiber, such as woolen cloth from the sheep's fleece and silk goods from the silkworm's cocoon.

"So common is the use made of chlorin as a bleaching agent that there are many factories devoted solely to its preparation. To make it portable and convenient for use we store it up, as we might say, in lime, which absorbs it freely. This compound is a white powder like lime itself, with a very strong and penetrating odor. It is called chlorid of lime and is a veritable storehouse of chlorin; and it is this that is commonly used whenever a powerful bleaching agent is needed.

4. CHLORIN IN PAPER-MAKING

"Now I must tell you about the part played by chlorin in paper-making. We commit our thoughts to writing without reflection on the many processes necessary to produce the white paper on which we write. Thousands of years ago the Assyrians of Babylon and Nineveh wrote with a sharp-pointed style on

an unhardened clay brick, which was then baked in an oven to fix the writing for all time. If any one wished to send a letter to a friend, it took the form of a brick similar in weight and size to those we use to-day for building."

"With a load of letters like that," said Emile, "postmen to-day would be so weighed down they couldn't stagger along."

"If it was desired to write a book," resumed his uncle, "for after ages to read,—a history of the memorable events of the time, for instance,—the work occupied whole shelves of a library, each page of the history being represented by one of these baked bricks. A single one of our printed volumes would have required in the writing enough bricks to build a house. You can judge from that how comparatively small must have been the amount of reading-matter in even a large library of those remote times, when each leaf was so bulky and cumbersome. A few remains of those ancient brick books have come down to us, having been dug up on the sites of Nineveh and Babylon; and these literary remains have even been deciphered and translated.

"Much later, another method of writing, no less strange in our eyes, came into use in those same regions of the East. A reed cut to a pen-point was the writing-instrument, and a black liquid made of soot stirred up in vinegar was the ink, while the paper was a bone, the broad flat shoulder-blade of a sheep, bleached by long exposure to the weather. A packet of writing on one subject—a book, in short—was made up of a number of these bones all tied together with a string.

"In the Europe of long ago, particularly in Greece and Rome, where civilization was most advanced, it was customary to use wooden tablets coated with a thin layer of wax, on which one wrote with a pointed instrument, a style, sharp at one end

and having a wide flat head at the other. The pointed end was used for tracing the characters in the wax, the flat end for erasing them and for smoothing the soft surface for fresh writing.

"Of all ancient peoples, the Egyptians came the nearest to inventing something like the paper of modern times. On the banks of the Nile there grows in abundance a kind of reed called papyrus, whose outer covering peels off in long strips, thin and white. These strips were soaked in the muddy water of the river, which served as glue, and were then arranged side by side, with a similar layer over them, but running crosswise. Pressed flat and beaten with a hammer, the whole made a sheet suitable to write on. Here again the pen was a pointed reed and the ink the same liquid prepared from soot. From the word 'papyrus' we get our word 'paper.'

"Papyrus sheets were not cut into small oblong pieces with square corners, such as we are so familiar with, but were made each in one continuous strip, its length varying with the amount of writing to be received. Hence, a papyrus book was all in one sheet or strip, which, for convenience in handling, was rolled around a little wooden cylinder to which the end of it was fastened. When we read a book we turn the leaves one by one, and these leaves have printing on both sides. The ancients followed a different method: they unrolled little by little the long strip of papyrus containing writing on only one side.

"The invention of paper is attributed to the Chinese. In the ninth century the Arabs introduced its manufacture in the nearer East, but its use did not become general in Europe until the thirteenth century. About the year thirteen hundred and forty the first paper factories were established in France.

Paper such as you have in the fair white leaves of your copy-books, and such as is used in making our more costly printed books, comes from the despised contents of the ragbag. Shreds and tatters are collected, some being taken out of the mud in the street, and some bearing the marks of unspeakable filth. They are sorted out, the better ones for fine paper, the inferior for coarse. After receiving a vigorous and much-needed washing, they are shredded until the woven fabric is reduced to lint, this process being the work of a cylinder equipped with sharp blades and revolving in a trough containing the rags soaking in water. Thus torn to bits, the rags are at last reduced to a sort of pulp or semi-liquid paste, which is gray in color and has to be thoroughly bleached before it can become the perfectly white paper so familiar to us. This bleaching is done by adding to the pulp, while the cylinder is still in motion, a weak solution of chlorin furnished by the chlorid of lime already mentioned. That is the office of chlorin in paper-manufacture, the bleaching of the rag-pulp to a spotless whiteness.

"But before paper can serve for writing on, it must be prepared in such a way that ink will not soak into it and spread in all directions, thus making the written characters illegible. To this end the pulp or paste receives a certain amount of what is known as size, made of resin and starch. If, however, the paper is intended for use in printing, this preparation is unnecessary; and that is why the paper of our books absorbs ink so freely if we try to write on it.

"The rag-pulp, bleached by chlorin and treated with resin and starch, is now ready for the final operation. With its bits of thread crisscrossing in all directions, it will presently come forth in a thin sheet that will be paper. A machine too com-

plicated to be described here accomplishes this final part of the process. The paste runs in a continuous film over a fine wire netting, which retains the coarser particles and lets the finer pass through. A second and still finer wire netting, moving on rollers, receives what falls from the first, retains the pulp, and drains off the water, the drainage being hastened by a slight side-to-side movement of the netting. In this way the rag-pulp is spread out in a uniform thin layer. Carried onward by the netting on which it is spread, this layer, this undried sheet, is brought into contact with a broad woolen belt, to which it clings, and by which it is conveyed over a hollow cylinder heated within by steam. On this cylinder the paper becomes dry and firm, after which it is rolled up on a second cylinder in a continuous broad strip of indefinite length. A few minutes only are needed to transform the semi-liquid pulp in the trough into paper ready for use. All that has to be done after this is to cut the strip rolled up on the last cylinder into sheets of the desired size.

"In future, whenever you read a printed page or write in your copy-book, remember that we owe the beautiful whiteness of the paper to chlorin, the gas made from our common salt."

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 An Experiment with Table Salt

1 What are the characteristics of sodium?
2 Why does potassium, or sodium, burn when put on water?
3 How may we obtain chlorin?
4 How does chlorin differ from most other gases?
5 How does chlorin affect man?
6 In what respect is the composition of table salt interesting?

2 The Bleaching Power of Chlorin

7 What advantages do we obtain from the use of chlorin?
8 Why does printers' ink resist the bleaching power of chlorin?

3 Chlorin in Cloth-Making

9 How does chlorin aid in the making of cloth?
10 What gives value to linen, cotton, or hemp?
11 In what form is chlorin ordinarily used?

4 Chlorin in Paper-Making

12 How did ancient book-making differ from modern book-making?
13 Tell about some of the odd books of ancient times.
14 Explain the origin of paper.
15 Explain the process of paper-making.
16 What does civilization owe to chlorin?
17 What values does the essay gain through the use of the story form?

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THE DISCOVERY OF RADIUM

By

MADAME MARIE SKLODOWSKA CURIE

Reprinted from Ellen S. Richards Monographs No. 2, published by Vassar College, THE DISCOVERY OF RADIUM, *address by Madame M. Curie, by permission of the Bureau of Publication, Vassar College.*

"It is my earnest desire that some of you should carry on this scientific work, and keep for your ambition the determination to make a permanent contribution to science."

M. CURIE.

MADAME MARIE SKLODOWSKA CURIE

(1867-)

Marie Sklodowska Curie, in 1911 winner of the Nobel Prize in Chemistry, is a distinguished scholar and patient investigator, modest in personality, and eager to serve mankind. During the World War she planned helpful radium service for French military hospitals. She aided the Radium Institute of Paris, and the Radioactivity Laboratory of Warsaw, in Poland. Because of her scientific achievements and her gracious personality, she so won the admiration of the United States that in 1921 the American women, through the agency of President Harding, gave her public tribute, and presented her with a gramme of radium.

Marie Sklodowska was born in Poland, the daughter of a Polish professor. In Paris, where she went to study science, she met the French physicist, Dr. Pierre Curie, Professor in the Sorbonne, whom she married in 1895. Following the discoveries of Henri Becquerel, in 1896, concerning radioactive characteristics in uranium, Madame Curie and her husband began a series of investigations of pitchblende, a black or brown, pitch-like mineral substance. Hampered by lack of money, without proper equipment, and working in an old shed, the two scientists carried on their task month after month, and at last discovered radium and polonium, naming the latter in honor of Madame Curie's native Poland. Because of their work they won the recognition of the Royal Society, that awarded them the Davy Medal, and a division with Henri Becquerel of the Nobel Prize in Physics.

In 1906, when Professor Curie was accidentally killed on the streets of Paris, Madame Curie took his place as Professor in the University of Paris, and as Director of the Curie Laboratory in Paris.

PREFATORY NOTE

In her recent visit to America, Madame Curie conferred a special honor upon Vassar College by delivering in the chapel on the evening of May fourteenth, 1921, the only extended address which she made in this country. In a simple, straightforward way she told the story of her great achievement. One realized how, closely environed by all the great realities of human experience, in the face of tremendous difficulties and with limited resources, she had pursued undaunted her search for truth.

The discovery of radium gave Madame Curie immediate distinction among scientists on account of the extreme significant contribution she thereby made to the great ultimate problem of physical science, the constitution of matter. The striking properties possessed by radium gave to its discovery a world-wide interest, all the more intense because of the hope which was inspired by the possible healing qualities of the radiations from this new element.

That hope is being realized in large measure. It is therefore fitting that this address should have been given by Madame Curie at Vassar and that it should now be circulated among the members of the college under the foundation in memory of Ellen S. Richards, who devoted her life to the public health.

EDNA CARTER,
Chairman of the
Department of Physics,
Vassar College

THE DISCOVERY OF RADIUM

By Madame Marie Skłodowska Curie

I. THE GREAT DISCOVERY

I COULD tell you many things about radium and radio-activity and it would take a long time. But as we cannot do that, I shall only give you a short account of my early work about radium. Radium is no more a baby; it is more than twenty years old, but the conditions of the discovery were somewhat peculiar, and so it is always of interest to remember them and to explain them.

We must go back to the year 1897. Professor Curie and I worked at that time in the laboratory of the School of Physics and Chemistry[1] where Professor Curie held his lectures. I was engaged in some work on uranium rays which had been discovered two years before by Professor Becquerel. I shall tell you how these uranium rays may be detected. If you take a photographic plate and wrap it in black paper and then on this plate, protected from ordinary light, put some uranium salt and leave it a day, and the next day the plate is developed, you notice on the plate a black spot at the place where the uranium salt was. This spot has been made by special rays which are given out by the uranium and are able to make an impression on the plate in the same way as ordinary light. You can also test those rays in another way, by placing them

[1] School of Physics and Chemistry. *Ecole de Physique et de Chimie, Paris.*

Ewing Galloway, N. Y.

MARIE SKLODOWSKA CURIE
Devoted Wife, Expert Physicist and Chemist, Discoverer of Radium

on an electroscope.[2] You know what an electroscope is. If you charge it, you can keep it charged several hours and more, unless uranium salts are placed near to it. But if this is the case the electroscope loses its charge and the gold or aluminum leaf falls gradually in a progressive way. The speed with which the leaf moves may be used as a measure of the intensity of the rays; the greater the speed, the greater the intensity.

I spent some time in studying the way of making good measurements of the uranium rays, and then I wanted to know if there were other elements, giving out rays of the same kind. So I took up a work about all known elements, and their compounds and found that uranium compounds are active and also all thorium compounds, but other elements were not found active, nor were their compounds. As for the uranium and thorium compounds, I found that they were active in proportion to their uranium or thorium content. The more uranium or thorium, the greater the activity, the activity being an atomic property of the elements, uranium and thorium.

Then I took up measurements of minerals and I found that several of those which contain uranium or thorium or both were active. But then the activity was not what I could expect; it was greater than for uranium or thorium compounds, like the oxides which are almost entirely composed of these elements. Then I thought that there should be in the minerals some unknown element having a much greater radioactivity than uranium or thorium. And I wanted to find and to separate that element, and I settled to that work with Professor Curie. We thought it would be done in several weeks or months, but it was not so. It took many years of hard work to finish that task. There was not *one* new ele-

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[2] Electroscope. An instrument for discovering the presence of electricity upon a conductor.

ment; there were several of them. But the most important is radium, which could be separated in a pure state.

All the tests for the separation were done by the method of electrical measurements with some kind of electroscope. We just had to make chemical separations and to examine all products obtained, with respect to their activity. The product which retained the radioactivity was considered as that one which had kept the new element; and, as the radioactivity was more strong in some products, we knew that we had succeeded in concentrating the new element. The radioactivity was used in the same way as a spectroscopical test.[3]

2. DIFFICULTIES IN THE WORK

The difficulty was that there is not much radium in a mineral; this we did not know at the beginning. But we now know that there is not even one part of radium in a million parts of good ore. And, too, to get a small quantity of pure radium salt, one is obliged to work up a huge quantity of ore. And that was very hard in a laboratory.

We had not even a good laboratory at that time. We worked in a hangar where there were no improvements, no good chemical arrangements. We had no help, no money. And because of that, the work could not go on as it would have done under better conditions. I did myself the numerous crystallizations which were wanted to get the radium salt separated from the barium salt, with which it is obtained, out of the ore. And in 1902 I finally succeeded in getting pure radium chloride and determining the atomic weight of the new element, radium, which is 226, while that of barium is only 137.

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[3] Spectroscopical test. An examination of the spectra, or images, formed by rays emitted from various substances or bodies.

Later I could also separate the metal radium, but that was a very difficult work; and, as it is not necessary for the use of radium to have it in this state, it is not generally prepared that way.

3. PRACTICAL USES OF RADIUM

Now, the special interest of radium is in the intensity of its rays, which is several million times greater than the uranium rays. And the effects of the rays make the radium so important. If we take a practical point of view, then the most important property of the rays is the production of physiological effects on the cells of the human organism. These effects may be used for the cure of several diseases. Good results have been obtained in many cases. What is considered particularly important is the treatment of cancer. The medical utilization of radium makes it necessary to get that element in sufficient quantities. And so a factory of radium was started, to begin with, in France, and later in America, where a big quantity of ore named carnotite is available. America does produce many grams of radium every year but the price is still very high because the quantity of radium contained in the ore is so small. The radium is more than a hundred thousand times dearer than gold.

4. RADIUM AND SCIENCE

But we must not forget that when radium was discovered no one knew that it would prove useful in hospitals. The work was one of pure science. And this is a proof that scientific work must not be considered from the point of view of the direct usefulness of it. It must be done for itself, for the beauty of science, and then there is always the chance that

a scientific discovery may become, like the radium, a benefit for humanity.

But science is not rich; it does not dispose of important means; it does not generally meet recognition before the material usefulness of it has been proved. The factories produce many grams of radium every year, but the laboratories have very small quantities. It is the same for my laboratory, and I am very grateful to the American women who wish me to have more of radium, and give me the opportunity of doing more work with it.

The scientific history of radium is beautiful. The properties of the rays have been studied very closely. We know that particles are expelled from radium with a very great velocity, near to that of the light. We know that the atoms of radium are destroyed by expulsion of these particles, some of which are atoms of helium. And in that way it has been proved that the radioactive elements are constantly disintegrating, and that they produce, at the end, ordinary elements, principally helium and lead. That is, as you see, a theory of transformation of atoms, which are not stable, as was believed before, but may undergo spontaneous changes.

Radium is not alone in having these properties. Many having other radioelements are known already: the polonium, the mesothorium, the radiothorium, the actinium. We know also radioactive gases, named emanations. There is a great variety of substances and effects in radioactivity. There is always a vast field left to experimentation and I hope that we may have some beautiful progress in the following years. It is my earnest desire that some of you should carry on this scientific work, and keep for your ambition the determination to make a permanent contribution to science.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The Great Discovery

1 What scientific work prepared the way for the work of Madame Curie?
2 How did Madame Curie happen to discover radium?
3 Explain the apparatus that Madame Curie used.
4 What shows Madame Curie's spirit of investigation?
5 Point out and explain the steps in Madame Curie's work in the discovery of radium.

2 Difficulties in the Work

6 What difficulties did Madame Curie overcome?

3 Practical Uses of Radium

7 What is the practical value of radium?
8 Why is radium expensive?

4 Radium and Science

9 For what purpose did Madame Curie work?
10 Why should not scientific work be carried on directly for usefulness?
11 What are some of the remarkable characteristics of radium?
12 How did the discovery of radium affect the atomic theory?
13 What fields of investigation are still open?
14 What characteristics of Madame Curie's personality does the talk reveal?

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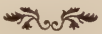
THE ATOMIC THEORY

By

EDWARD NEVILLE DA COSTA ANDRADE

Reprinted from WHAT IS THE ATOM? *by Professor E. N. da C. Andrade, by permission of the publishers, Harper and Brothers, London, England.*



"The atomic theory is to chemistry what book-keeping and accountancy are to business."

E. N. DA C. ANDRADE.

EDWARD NEVILLE DA COSTA ANDRADE

(1887-)

The noted physicist and author of scientific works, E. N. da C. Andrade, has been professor of Physics in Artillery College, Woolwich, England, since 1920. In his student days in St. Dunstan's College, the University College of London, the University of Heidelberg, the Cavendish Laboratory of Cambridge, and the University of Manchester, he won honors for high scholarship. During the World War he served in France as an officer in the British forces.

Professor Andrade is the author of *The Structure of the Atom, Airs, The Atomic Theory,* and of many articles on physical and mathematical subjects. A number of his important papers appear in the *Proceedings of the Royal Society.*

THE ATOMIC THEORY

By Edward Neville da Costa Andrade

I. WHAT MATTER IS MADE OF

FROM the time when serious thinking about ourselves and our surroundings began, the question has been asked as to what matter is made of. In particular, the following problem has been discussed: Suppose we could take a piece of some substance, say copper, and magnify it indefinitely, should we see in the end that it was made up of particles with spaces between them, held together by certain attractive forces, or should we find that, no matter how much larger we made it appear, it was as continuous throughout as it appeared when unmagnified? To take a homely simile, would it appear like a bushel of peas, or like a jelly? Another way of asking this question is to demand whether, supposing our senses were fine enough and our instruments delicate enough, we could go on dividing up a piece of matter, say, copper, into smaller and smaller fragments indefinitely, or whether we should at last come to a fragment which could not be further divided, at any rate without its ceasing to be copper. On the bushel of peas theory, we should come to an end when we had isolated a single pea, while we could go on chopping our little bit of jelly smaller and smaller without coming to a recognizable ultimate part.

The atomic theory is the bushel of peas theory. It assumes that all matter is ultimately made up of little grains which are called atoms because they cannot be further divided. For the

word "atom" is derived from a Greek word meaning "that which cannot be cut." Until within the last twenty or thirty years it was believed that an atom could not be damaged in the slightest, but we know now that we can chip little bits off atoms. The exact meaning of this will be discussed later on: it is not of importance for our present purpose. If, changing our metaphor, we call atoms the bricks out of which pieces of matter—of copper, quicksilver, carbon, and suchlike—are built, they are no less our ultimate bricks because we can, by certain methods, chip little pieces from them. We cannot cut them in half, and have two half-bricks.

The question at once arises as to how many different kinds of atoms we must assume. We are acquainted with hundreds of thousands of different kinds of substances: with different metals, different woods, different stones; with the parts of living organisms, such as bones and flesh; with the enormous variety of different chemical substances which play so large a part in our life and industry, and, in contrast, with ill-defined messes, such as mud, and the products of the average cook. Are we to assume that to each substance corresponds a different atom: that the ultimate constituent of copper is a little atom of copper, the ultimate constituent of bone a little atom of bone, and the ultimate constituent of mud a little atom of mud? The last would clearly be absurd, for we know that mud is made by mixing various things; for instance, water, clay, and the little particle of wood, stone, cloth, and what not which we call dust, so that in any case it will be sufficient to discuss the ultimate parts of these things which are mixed. Suppose, then, we confine ourselves for the moment to definite chemical substances, such as copper and quicksilver, salt and sugar, water and alcohol, and inquire about their ultimate

structures. Are they simple things, each with its own kind of atom, or can they be built up of other substances?

2. THE ELEMENTS

The answer, provided by the science of chemistry, is that certain substances are simple, and cannot by chemical means be built up of other substances, but that the vast majority of substances are compounds, which can be made in the laboratory (if not in the laboratory of flasks and test tubes, then in the wonderfully equipped laboratory which is constituted by any living substance) from the simple substances. Thus the solids, copper, sulphur, carbon; the liquids, quicksilver, and bromine; the gases, oxygen, nitrogen, and hydrogen, are examples of simple substances, which cannot be manufactured by making substances combine. Such substances are called elements.[1] Some ninety elements, in the sense just defined, are known. Familiar substances which are elements are the pure metals (as distinct from alloys), such as aluminium, iron, cobalt, nickel, zinc, platinum; the non-metallic solids, carbon, arsenic, iodine, and phosphorus; and the liquids and gases just mentioned. Some of these elements occur much more commonly than others; thus the eight elements, oxygen, silicon, aluminium, iron, calcium, magnesium, sodium and potassium make up nearly ninety-nine-hundredths by weight of the earth's crust, while the fifty least common elements, which include many useful metals, all together constitute only about one ten-thousandth of the earth's crust. It will come as a surprise to many that oxygen is the commonest element, not, of course, as a gas, but because it is combined in important proportions by weight in nearly all common substances.

[1] The use of the word element to denote the four supposedly, but not actually, simple substances earth, air, fire, and water, is a relic of ancient Greek belief, and has no place in modern science.

From these elements all known substances are built up, just as from a few types of girders, beams, plates, and so on, the steel work of all structures, bridges of various sizes and shapes, towers, and suchlike can be made. Thus ordinary kitchen salt is a compound of the soft metal sodium and the gas chlorine, while sugar is composed of carbon, oxygen, and hydrogen. Marble is composed of calcium, carbon, and oxygen; hydrogen peroxide, by which blondes are manufactured, of oxygen and hydrogen. These substances will serve to illustrate a few of the facts of chemistry which we require for our discussion. In the first place we see that when elements combine, the obvious properties of the compound have nothing to do with the properties of the elements from which it is made. Sodium is a soft substance, which can be cut with a knife, leaving a metallic surface which tarnishes at once in air; if thrown into water, it floats, and decomposes the water so vigorously that, in certain circumstances, combustion and explosions may ensue. Chlorine is poisonous to breathe; in fact, it was the first gas to be used as poison gas in the Great War. Yet chlorine combines readily with sodium to form ordinary salt, which is wholesome, and dissolves in water without fuss. When marble is acted upon by acid, the carbon and part of the oxygen are given off, combined together to form the familiar gas carbon dioxide, used to aerate drinks. Carbon—or coke—and the two gases, hydrogen and oxygen, combined in due proportions, form sugar; combined in other proportions, they form starch. Oxygen and hydrogen combined in certain proportions form water; in other proportions, hydrogen peroxide. We see, therefore, that in a compound the properties of the combining substances are completely hidden; the substance resulting from a chemical reaction between different substances does not show a kind of average of their qualities, but has its own dis-

tinct individuality. In the second place, substances combine in perfectly definite proportions by weight to form a given substance; they are not mixed, like the ingredients of a pudding, where a little more or less of any one component may be allowed without altering the result, but put together in a precise way like a machine, where an exact number of component parts are required. In the third place, the same elements can combine in different proportions, forming quite different substances; but when they do so, the proportions by weight of the elements in the different compounds bear quite simple relations to one another. For instance, in hydrogen peroxide, there is exactly twice as much oxygen combined with a given weight of hydrogen as there is in water; the weight of oxygen combined with a given weight of lead in pure red lead (plumbers' red lead is usually a mixture) is four as against six in the brown lead peroxide formed on the positive plate of an accumulator, and three in the oxide of lead known as litharge. These are particularly simple examples, but the laws just indicated are quite general.

3. CHEMICAL COMPOUNDS

Now on the atomic theory these laws are simply explained in the following way. Chemical compounds are formed by the atoms of different elements entering into combination with one another. For simplicity we will consider for the moment compounds formed of two different elements only, such as common salt. In such compounds quite a few atoms—perhaps one, and seldom more than six—of an element combine with quite a few atoms of another element to form the smallest particle which can have the properties of the substance in question. Such a particle is called a molecule: for an elementary substance the atom and the molecule may be the same

thing. In the case of common salt, one atom of sodium combines with one atom of chlorine to form one molecule of salt, which is called in chemical language sodium chloride. In the case of carbon and oxygen, one atom of carbon combines with one atom of oxygen to form one molecule of carbon monoxide, which is a highly poisonous gas, formed by incomplete combustion: a favorite French method of committing suicide with a charcoal brazier in a closed room depends upon the production of this gas, one part of which to a thousand parts of air is fatal. One atom of carbon can also combine with two atoms of oxygen to form carbon dioxide. The weight of oxygen combined with an ounce of carbon is twice as great in carbon dioxide as in carbon monoxide. Iron forms two compounds with chlorine, in which the weights of chlorine combined with a given weight of iron are as two to three: in the one compound one atom of iron is combined with the two atoms of chlorine; in the other compound, one atom of iron is combined with three atoms of chlorine. This conception of atoms combining explains why in true chemical compounds the proportions are always fixed, since every ultimate part of the compound consists of a perfectly definite small number of one kind of atom combined with a perfectly definite small number of another kind of atom; it also explains why, when the same two elements combine to form different compounds, the amount of the one element combined with a fixed amount of the other element, while different in the different compounds, is always a very small multiple of a fixed amount.

To make this quite clear, let us consider a business office which buys envelopes at a fixed rate, and franks all its letters with stamps of the same denomination, and let us further imagine that it has different departments for dealing with correspondence requiring different postage. Thus, one depart-

ment sends out printed leaflets requiring a single stamp on the envelope; another department sends out cards, requiring two stamps; another department letters requiring three stamps; another department foreign letters requiring five stamps. In a given department the ratio of the amount spent on envelopes to the amount spent on stamps will always be the same; in another department it will be different, but the amount spent on stamps per envelope will be a simple multiple of that prevailing in the first department. Anybody investigating the books of the business would come to the conclusion that the costs would be most simply explained by supposing that a single envelope combined with a single stamp in one department, and with two, three, or more stamps in other departments. Substitute weights for costs, and compounds for departments, and we have the chemical facts.

The importance of the atomic theory in chemistry is that it enables us to form a picture of what is going on when chemical combination takes place, and to anticipate what we must do to form a given molecule. It is not too much to say that without this scheme of combining atoms, and atoms taking the place of others in a molecule, we should have none of the synthetic dye-stuffs that we possess to-day. By means of the atomic theory, we can write down exactly what quantities of substances are required to take part in a given reaction, and can foretell what steps must be taken when it is desired to form one compound from another. The atomic theory is to chemistry what bookkeeping and accountancy are to business. We might carry on somehow without it, but we should have no control of our knowledge, no systematic record of our achievements to which we could refer, no reasoned lines for planning future campaigns.

4. SOLIDS, LIQUIDS, AND GASES

We now turn to the application of the atomic theory to certain general aspects of the nature of matter, and in particular to the nature of heat. Matter as we know it can exist in three forms, as a solid, a liquid, or a gas, and a given substance can take on one or the other form, according to the temperature and pressure. Thus, to take the familiar example of water, it is a solid, ice, when very cold; a liquid, under ordinary conditions; and an invisible gas, steam, when very hot, the temperature at which it turns into steam depending on the pressure, as every engineer knows. We say that steam is an invisible gas, for what is ordinarily called steam is minute drops of hot water, formed by the steam condensing in the cold air: close to the spout of a kettle there is a space where the issuing steam cannot be seen. A somewhat less familiar example of the three states is the gas, carbon dioxide, used for making aerated drinks, which has already been mentioned. This is sold in steel cylinders, in which it exists under great pressure as a liquid. When it is let out slowly with the tap end of the cylinder uppermost it issues as an invisible gas, but if the cylinder be reversed and the liquid allowed to issue rapidly, intense cold is produced, and a snow-like substance is formed, which may be caught in a cloth wrapped round the nozzle. It is carbon dioxide in solid form. All substances which exist normally as gases, including the air we breathe, can nowadays be reduced to liquid and to solid forms: liquid air can, in fact, be bought commercially, like milk. The last gas to be subdued was helium, which was not reduced to solid form until 1926. Whether a substance exists as a solid, a liquid, or a gas, does not, in fact, depend upon the substance, but upon the conditions. If the normal temperature of the

world were that of an oven, we should (provided we could exist) speak of water substance as a gas, which could be liquefied and solidified by special means, and similarly, we should regard the metal tin as a liquid.

How are we to regard these different forms of matter on the atomic theory? We must first say a word as to the nature of heat. Every body is made up of atoms, bound together in little knots or molecules if the body is a compound, and not an element. These molecules are in ceaseless agitation, and so possess energy of motion. This invisible, or internal, energy, due not to the motion of the body as a whole, but to a dashing hither and thither of particles much too minute to be seen even with a microscope, constitutes heat. It is taking place in bodies at ordinary temperatures, but when we heat a body it becomes more violent, when we cool a body it becomes less marked. In a heat engine of any kind, we convert some of the invisible molecular motion into a visible motion of the piston. From this view of heat we see at once a very important fact—namely, that there must be a limit of coldness, or an absolute zero of temperature below which we cannot go. For when a body is cold enough for all molecular motion to cease we cannot go to any lower temperature: molecules cannot be any less lively than still. It can be calculated that this so-called absolute zero of temperature is 273 degrees centigrade below the melting-point of ice, and temperatures within less than one degree of this have actually been attained in the laboratory. On the other hand, there is no limit of high temperature, for however energetically the molecules may be dashing about they can always go faster. It can be estimated that the temperature in the interior of certain stars is to be measured in millions of degrees, but it is inconceivable that anywhere can exist a temperature lower than 273 degrees centigrade below zero.

Now in matter we have a conflict between two influences. In the first place, the molecules attract one another, and so tend to settle down into a state where all the particles are bound firmly together by the forces which they exert on one another. Against this we have the movement of the molecules which constitutes heat: every one of them is in ceaseless agitation, except in the case where the temperature is near the absolute zero. The higher the temperature, the more violent the motion of the molecules. This motion tends to keep the molecules from settling down, and in this sense acts in the opposite way to the attractive forces. Whether a body exists in the solid, liquid or gaseous state depends upon the relative importance of the two effects.

In a solid the attractions prevail. The molecules occupy more or less fixed positions, depending upon the forces exerted by the other molecules, and their heat motion consists of a vibration or trembling of the molecule, which never takes it far from its fixed abode. In a liquid the attractions and the heat motions are more evenly balanced, so that, while the attractions play a considerable part, yet any molecule can work its way through the other molecules. It makes frequent collisions with them, but can slowly move by itself to a distant spot, or, if we care to stir the liquid, we can move some molecules farther away from others. In a gas at ordinary pressure, the molecules are generally sparsely scattered, the attractions are relatively unimportant, and the molecules move in straight lines over distances which are large compared to the size of a molecule, and act on one another mainly by collisions. The pressure which a gas exerts is merely the effect of a bombardment on the side of the containing vessel by millions of millions of tiny molecular projectiles, which bounce off again. In a solid and a liquid the molecules are comparatively close, and

the substance can only be compressed with difficulty: in a gas the molecules are separated by long distances, and the substance can be compressed easily.

When we heat a substance we increase the energy of the heat motion of the molecules, by communicating to them some of the energy of motion of the molecules of the heating body —flame or what not. Hence, although in the beginning the attractive forces between the molecules may be the predominating influence, as the temperature rises the heat agitation eventually becomes sufficient for the molecules to shake themselves loose from their moorings, as it were, and go cruising through the compact fleet which they constitute. The solid becomes a liquid. At a still higher temperature, the motion becomes so violent that the molecules fly off altogether from one another, and go shooting about with high velocity, the attraction only being appreciable when two molecules happen to collide, and then being insufficient to hold them together.

We can form a rough human picture of what is going on, in the following way. In a solid, the molecules can be pictured as a crowd of men all doing physical exercises—"the daily dozen"—without moving from the spot where they stand. If they have taken up their positions at random, we have a so-called amorphous or non-crystalline solid, such as glass or glue: if they are neatly drawn up in rows by a drill instructor, we have a crystalline substance, such as quartz or rock-salt or washing soda. In a liquid the molecules can be pictured as a swarm of men gathered together in a hall at a crowded reception; they are tightly wedged, but each one works his way through the others, with many a push and apology, and we cannot expect the same two men to be near each other all through the evening. (If we want two kinds of atoms, we may take men and women; if dancing starts we have chemical

combination, two atoms combining to form a molecule.) For a gas we have to think of a large open space on which men are walking without looking where they are going; each man continues in a straight line until he bumps into someone else, when he abruptly starts off again in a different direction. In each case, the hotter the substance the more rapid the motion. If a cinematograph picture could be taken of the molecules of the air in a room all we should have to do to represent the air in an oven would be to run the film more quickly.

We have now obtained some idea of the outlines of modern atomic theory. A piece of copper wire appears to be continuous and inert only because of the minuteness of the molecules, just as a large and animated crowd may appear to an observer high in an aeroplane merely as a tranquil brown patch. When chemical combination takes place, what really happens is a regrouping of atoms according to certain definite laws, just as, from a mixture of people, families will segregate.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 What Matter Is Made Of

1 In general terms, explain the atomic theory.
2 How does Professor Andrade make his paragraphs clear?
3 Are there different kinds of atoms?

2 The Elements

4 What is the nature of an element?
5 Why is oxygen the most common element?
6 How do substances differ from the elements of which they are composed?

3 Chemical Compounds

7 Explain the characteristics of a molecule.
8 Why are the proportions in true chemical compounds always fixed?
9 Point out examples of familiar comparison for the sake of clearness.

4 Solids, Liquids, and Gases

10 Explain the importance of the atomic theory.
11 Name and explain the three forms of matter.
12 What is "absolute zero"?
13 Why is there no limit for high temperature?
14 What are the effects of heat?
15 Summarize what the article says concerning the atomic theory.
16 Why does the atomic theory arouse the spirit of wonder and of investigation?

BOOKS FOR FURTHER READING

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THE AUTOBIOGRAPHY OF AN ELECTRON

By

CHARLES ROBERT GIBSON

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"An electron is a real particle of negative electricity."

CHARLES R. GIBSON.

CHARLES ROBERT GIBSON
(1870-)

Charles Robert Gibson's popular scientific books, written in English, and translated into Italian, Dutch, German, Spanish, Hungarian, Japanese, Esthonian and Arabic, have played a notable part in spreading scientific information. Mr. Gibson, who is a resident of Glasgow, Scotland, is a member of various learned societies, was for three years President of the Royal Philosophical Society of Glasgow, and is a Fellow of the Royal Society of Edinburgh.

AUTOBIOGRAPHY OF AN ELECTRON

By Charles Robert Gibson

PRELIMINARY DEFINITIONS

It will be well to keep clearly in mind that an electron is a real particle of negative electricity.

Electrons were discovered only within recent years.

No matter from what substances we take them, they are always identical in every respect.

Some electrons are attached to the atoms of matter in such a way that they may be removed easily from one object to another.

When a surplus of these detachable electrons is crowded on to any object, we say that it is charged with negative electricity.

We speak of the other object, which has lost these same electrons, as being charged with positive electricity.

In this article the electron refers to the old-world experiment in which a piece of amber when rubbed attracts any light object to it.

For many ages man believed this to be a special property belonging to amber alone.

One of Queen Elizabeth's physicians discovered that this property was common to all substances.

I. THE NEW ARRIVAL

IT IS most amusing to me and my fellow-electrons to hear intelligent people speak of us as though we were new arrivals on this planet. Dear me! We were here for countless ages before man put in an appearance. I wonder if any man can realize that we have been on the move ever since the foundations of this world were laid. It is man himself who is the new arrival.

It does seem strange to us that men should be so distinctly

different from one another. We electrons are at a decided disadvantage, for we are all identical in every respect. I have no individual name—it would serve no purpose. Even if you could see me, you could not distinguish me from any other electron. I wonder sometimes if men appreciate the great advantage they have in possessing individual names. I was impressed with this thought one fine summer morning. While I was riding on the back of a particle of gas in the atmosphere, I was carried through the open window of a nursery just as the under-nurse was putting the room in order. A little later there was some commotion in the nursery, for the young mother and her mother had come to see the twin daughters being bathed by the nurses. The grandmother happened to remark how very much alike the two little infants were. She said laughingly to the head nurse that she must be careful not to get the children mixed. But the big brother, aged five years, remarked that it would not matter really how much they were mixed until they got their names. Sometimes I wish we electrons did differ from one another, so that we might each possess an individual name, but no doubt it is necessary for us all to be exactly alike.

Long before man had discovered us, he caused us deliberately to do certain things. He was mystified by the results of his experiments, for he was not aware of our presence. A few of my fellow-electrons have rather hazy recollections of being disturbed while clinging to a piece of amber. They had been disturbed often before in a similar way, by being rubbed against a piece of woollen cloth, and the result had been always that a number of electrons let go their hold upon the cloth and crowded on to the amber. The overcrowding was uncomfortable, but it happened usually that the surplus electrons found

some means of escape to the earth, where there is no need of excessive crowding.

On the occasion to which I refer, it so happened that the rubbing had been unusually vigorous and prolonged, so that the electrons were crowded on to the amber in great numbers. In their endeavor to escape they produced a strain or stress in the surrounding ether, and this caused a small piece of straw, which was lying within the disturbed area, to be forced towards the amber.

What attracted the attention of the electrons was that the man who was holding the piece of amber removed the clinging straw and replaced it exactly where it had been lying. In the meantime he had been handling the amber, and many of the crowded electrons had managed to make a bolt for the earth by way of the man's body. They did this so very quietly that the man did not feel any sensation. However, as soon as the amber was rubbed again, a similar crowd provided the same attractive property. We electrons became impatient to hear what man would say of our work, for it was apparent that he had noticed the movements of the straw. You will hardly believe me when I tell you to what decision these wise men of the East came. They declared that, in rubbing the amber, it had received heat and life. As if life could be originated in any such simple manner!

You can picture our disappointment when we found that man was going to ignore our presence. Occasionally we were given opportunities of displaying our abilities in drawing light objects towards pieces of rubbed amber. But the funny thing was that man got hold of the stupid idea that this attractive property belonged to the amber instead of to us. If he had only tried pieces of sulphur, resin, or glass, he would have found that these substances would have acted just as well.

You see it was not really the substance, but we electrons who were the active agents.

We had given up all hope of being discovered, when news came along that a learned man was on the hunt for us. He was crowding us on to all sorts of substances. He rubbed a piece of glass with some silk, and at first he was surprised greatly to see light objects jump towards the excited glass. Of course, we were not surprised in the very least. The only thing that amused us was to find that he was making out a list of the different substances which showed attractive properties when rubbed. He could not, evidently, get away from the idea that it was the substances themselves that became attractive.

We were sorry that the poor experimenter wasted so much time and energy in trying to crowd us on to a piece of metal rod. He rubbed and he rubbed that metal, but it would attract nothing, and I shall tell you the reason. You know that we electrons hate overcrowding; indeed we always separate from one another as far as possible when there is no force pulling us together. We only crowded on to the amber because we could not help ourselves; we had no way of escape, for amber is a substance we cannot pass through. But we have no difficulty whatever in making our way along a piece of metal, and as soon as the rubbing began, some electrons moved off the metal by way of the man's arm and body to make room for those being crowded on to the metal from the rubber. And so there never was any overcrowding, and consequently no straining of the ether. But it was not long before we found that man had succeeded in cutting off our way of escape. He had attached a glass handle to the metal rod, and we were compelled to overcrowd upon the metal as we could not pass through the glass handle. Neighboring

light objects were attracted by the excited or "electrified" metal. Even this demonstration did not put man upon our track.

Perhaps I should explain in passing, that when a glass rod is rubbed with a silk handkerchief we crowd on to the silk, and not on to the glass. This leaves the glass rod short of electrons, and the ether is strained so that light objects are attracted. Man did notice that there was some difference between a piece of amber and a piece of glass when these were excited. What the difference was he could not imagine, but to distinguish the two different conditions he said that the amber was charged with *negative* electricity and the glass with *positive* electricity.

From that time forward man became of special interest to us. We felt sure that sooner or later he was bound to recognize that we were at work behind the scenes. It seemed to us, however, that man was desperately slow in turning his attention towards us.

2. MAN PAYS US SOME ATTENTION

From the little I have told you already of our experiences, you will see that men had been making many experiments in which we electrons took a very active part. It was disappointing that even although we had surprised man in so many different ways, he had never become suspicious of our presence. One day, however, we did begin to hope for recognition. I was present, with a great crowd of electrons, imprisoned within a glass globe from which the air had been extracted. We were very pleased to find that the surrounding space had been cleared of air, for it was apparent that the experimenter was going to make us jump across from one end of the glass tube to the other.

A crowd of us had collected on the extremity of a wire, or "electrode," at the one end of the tube, while another similar crowd was present on the other electrode at the opposite end of the tube. While I speak of a crowd, meaning that there were millions of us, I do not suggest that we were overcrowded, for we had plenty of elbow-room to move about on the atoms to which we were attached. All in a moment the scene was changed. We felt a crowd of electrons pressing us forward and forcing us right up to the very end of the electrode. We found that the crowd was approaching by a wire leading into the tube. Soon the crowding had reached such a condition that we became alarmed; we could see no way of escape. We were imprisoned by the glass walls, but we soon discovered that many of the electrons who had been stationed on the other electrode had deserted their posts and fled along a wire leading out of the tube. If we could only follow them. It would be a tremendous jump to get over to the other wire, but the way was fairly clear of air. When the overcrowding reached a certain point we were literally shot across from the one electrode to the other. This was the first time I had ever experienced anything of the kind, but many fellow-electrons had gone through similar performances for years at the hands of other experimenters.

However, it was somewhat alarming to be fired off like a rocket across the tube. What happened after that I cannot recollect, but some time later I was present in that or a similar tube when I heard the experimenter say to a friend that he believed there were particles flying across his tube. We sent news all along the line stating that at last we had been discovered, and I can assure you that we felt proud. But our joy was not long-lived, for it turned out that we were considered

to be particles or atoms of matter; the experimenter spoke of us as "radiant matter." This was a real disappointment.

It took us some time to recover from our disappointment at being mistaken for clumsy atoms of matter. We are of a higher order of things altogether. No atom of matter can travel at speeds such as we can. We cross these vacuum tubes with speeds equal to millions of miles per minute.

A great many of us were kept busy within vacuum tubes by other experimenters, but nothing very exciting happened. Indeed, we had lost all hope of attracting man's attention to ourselves as long as we were imprisoned within these tubes. In the meantime our hopes were revived by news which reached us from another quarter.

We heard that a very learned man [1] had declared boldly that there did exist little particles which revolved around the atoms of matter, and that it was the motion of these tiny particles in the ether which produced the well-known waves of *light*. There was considerable rejoicing among us, for we were anxious to have our services recognized by man. This great man was not guessing merely; he was willing to prove by mathematical calculations that we did exist in reality. Of course, we ourselves required no proof of our existence, but we believed that man would be convinced. Our high hopes were soon laid low; news reached us that people were shaking their heads and saying that figures could be made to prove anything.

After we had settled down to our ordinary duties, we got

[1] Learned man. Dr. G. Johnstone Stoney, in 1874 drew attention to natural units of electricity. In 1891 he suggested the name, "electron" as a suitable name for such a unit. Professor J. J. Thompson, in 1897, determined the velocity of an electron as between 20,000 and 50,000 miles a second.

The work of Sir William Crookes and also of Lord Kelvin led directly to the electron theory.

word that at last man had really detected us in a flame of gas. This seemed quite reasonable, for we have a very lively time of it in a flame of gas. However, when we were informed that man had discovered us by means of a sort of telescope arrangement, I, for one, began to doubt the truth of the discovery. Some time before this I had heard that men were spying at gas flames in the hope of finding us, and this seemed most ridiculous, for if man could not see the large congregations of us called *atoms,* how could he expect to see individual electrons? My ignorance was dispelled when it was explained that man had not been looking for us directly, but for the ether waves which we produce. But I have not had an opportunity of explaining to you how some of us produce waves in the ether; I shall have to wait till a later chapter. In the meantime I may say that since this important discovery I have taken some part in an experiment similar to the historic one wherein we were detected, but of that too I shall have more to say again.

The rejoicing at this discovery was not confined to us, for men of science were quick to grasp the importance which was attached to this new knowledge. We felt that man was bound to acknowledge our services from that day. The next event was our christening, and this was not all plain sailing. Indeed, we have been rather annoyed with one name which some good friends persist in giving us. I refer to the name *corpuscle,* which we feel to be a sort of nickname, although it may have been suggested in all kindness. It may be difficult for you to appreciate our dislike to this name, but it seems to us to savor too much of material things. It is not dignified; you must remember we are not matter. We are delighted with what we prefer to call our real name—electron—for that speaks of electricity. As you know, we are units or particles of nega-

tive electricity, and so this seems a most sensible and suitable name.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The New Arrival

1 What is an electron?
2 What is gained by ascribing personality to an electron?
3 What first attracted attention to electricity?
4 How did the ancients explain electricity?
5 How do we explain electricity?
6 Why did the early experimenters fail in their efforts to electrify iron?
7 How did the terms "negative" and "positive" electricity arise?

2 Man Pays Us Some Attention

8 How do we explain the action of electrodes?
9 How does an electron differ from an atom of matter?
10 What explains light?
11 Why is "corpuscle" an unsuitable term for an electron?
12 In what respects is the narrative form a good form for presenting scientific truth?
13 Write an original narrative in which you explain some other scientific subject besides the theory of electrons.

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A DROP OF WATER

By

HENSHAW WARD

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"Every particle of matter large enough to be seen is composed of quadrillions of regions of electrical energy. . . . And each one of the regions is a complication of secrets that are quite unfathomable."

HENSHAW WARD.

HENSHAW WARD

(1872-)

Henshaw Ward was born in Nebraska, fifty miles from a railroad, in 1872. In 1888 he went to Southern California to live, and in 1896 was graduated from Pomona College, where he elected all the courses he could carry in the elements of the sciences. The next two years he spent in the graduate school of Yale studying English literature, and the next twenty-four in teaching. In 1922 he retired from teaching, and set himself to popularizing science. His first book of science is *Evolution for John Doe* (1925), described by Professor Parshley as "the one and only book on evolution for the layman." A series of articles in *Harper's Magazine* described the latest and most marvelous advances in science; these, with some others, were made into a book called *Exploring the Universe* (1927). Next came a book that explained the weakness of mere logic and reasoning compared with science. *Thobbing: a Seat at the Circus of the Intellect* (1926). His most recent book is *Charles Darwin: the Man and His Warfare* (1927).

A DROP OF WATER

By Henshaw Ward

I. READY FOR ADVENTURE

ANYONE who joins me in this adventure does so at his peril. You are warned that you will be carried far beyond the limits of exact knowledge, and even beyond what the mind can conceive. If you have a nervous temperament you should on no account attempt this voyage through a drop of water.

Still, I am a careful pilot and shall steer to plain facts over a route that has been thoroughly charted by scientists. My trip is no more than a translation of their rigorous books, rendering their negative exponents into human language and adding some colors to help our eyes.

Before us hangs the object that we are to explore. It is a glittering little globe of the most common substance, a liquid composed of oxygen and hydrogen. Its diameter is an eighth of an inch. The chemist tells us about this drop of water by naming infinitesimal distances, like 1/100,000,000 of an inch. But no mind can visualize such distances or feel the least interest in them. The only way I can form any picture of the chemist's world is to enlarge it, and to keep enlarging it, until it finally becomes spacious enough for me to roam about and see things as they would appear if they were brought up to sizes with which I am familiar. My imagination wishes to sit in a comfortable chair and have big atoms parade for inspection.

So I have found pleasure in magnifying water until all its parts are large and plain. This I do by supposing that I am on a magic carpet which first takes me to a view of the drop as it would appear if increased fifty times in size, then to a view of this enlargement when made a thousand times larger still, and so on till I have sight of all that science knows. If you care for such a plaything, step aboard. Hold fast while we make the first stage of the journey beyond our eyesight.

2. ON THE SURFACE AND WITHIN

You feel a tremor for a moment, then a rush that makes you unconscious. When you open your eyes again, the drop is enlarged fifty times—to a diameter of six inches. Of course such a change in size is insignificant and reveals nothing; but, oddly enough, we are struck by the sight. Though we have never felt any curiosity about a drop of ordinary size that hangs from a twig, we now wonder how a six-inch mass of water holds itself together and supports itself. We note, as if through a new pair of eyes, that the drop is enlarged at the top and spread out in a clinging surface. It looks as if it had a strong, elastic skin.

When you step forward to get a closer view, you feel again the queer tremor, as if some force were stretching space apart and its dimensions were sweeping past you. The sensation is more severe and prolonged than the first one. As you return to consciousness do not resent the manhandling you have undergone. For, considering the transformation that has taken place in your neighborhood, you must admit that the process was not unduly painful. The six-inch drop of water is enlarged one thousand times, to a diameter of five hundred and twenty feet, and we are poised at its surface. Its rainbow

colors have disappeared, and it bends above us as a huge gray mass, chill and forbidding.

What curious creatures we are to gape and shudder at a large drop of water when we have never given a moment's thought to a small one. Our minds are true to their savage nature—blind to everything that is usual, excited by anything that is novel. Surely this five-hundred-foot sphere is no more remarkable, essentially, than an eighth-of-an-inch drop. The force which maintains the small drop is quite as far beyond our knowledge as the one that holds this large globe in shape.

It is not likely that we shall ever understand the power which piles up water in a drop on a dry surface. All we can ever do is to take a step toward the reality, give a name to the step, and thus make up a new formula for pupils to rehearse in school. The more steps we take, the more we shall see before us; the path to knowledge lengthens as the cube of any advance we can make on it.

So much by way of discouragement in this enterprise of enlarging a drop of water. You should be warned that no ultimate facts will be reached. Thus far the drop has been magnified fifty thousand times, yet we see nothing new. We look at a wall of water that remains as inscrutable as the ocean on a cloudy day.

If we had brought along a microscope, and if a molecule were a solid body that could be placed against a contrasting background, I could at this stage show you the molecules of water. But they would be the merest dim specks, meaningless and uninteresting. Travelers toward the interior of a drop must endure another enlargement of a thousand times if they are to see anything whatever. This third transformation will be more severe than the second one. Close your eyes and relax.

The discomfort you feel will soon pass off. Rest easily for a few minutes and adjust yourself slowly to the new surroundings while I give a warning about what you are to see.

Science does not know anything about the "feeling" or the "look" of any part of a molecule. The "sights" on the rest of our journey are purely fanciful. But they correspond in every particular to some realities, and they are far less bright and strange than the facts would be if they could in any way become apparent to our senses.

The drop is now nearly a hundred miles in diameter. In its last expansion it enclosed us, and we are now about ten miles within the surface. The flickering all about us is caused by the motions of molecules. They are nearly an inch in diameter, driving this way and that in swarms, bumping and recoiling, forming into masses and dispersing, darting without cessation.

Put out your hand and grab one. The strange sensation is not due to your nerves being unstrung, for you are now restored to a normal condition and are judging everything just as you would in a world where dimensions are fifty million times smaller. You can feel a molecule enclosed in your hand; it resists your squeezing as if it were a piece of marble. But you can see nothing. You can hardly tell whether the molecule weighs anything. The object in your hand appears to be a very firm bit of matter, which causes a stinging sensation on the palm of your hand; otherwise you can gain no conception of it.

If you could keep your hand out beyond the edge of our magic carpet, it would be hammered and rasped by the molecules in their continual hurtling against one another. If they were farther apart, so that some of them drove at us in full flight, we could not protect ourselves from them. But since

the distances between them are small and their motions are continually checked, it is possible to put up a barrier against them.

If you care to have any real view of a molecule, you must go through another thousand-times enlargement of the drop. Now that we have passed the third stage beyond the world of our senses, the transformation will be rather easy.

The drop has become a hundred thousand miles in diameter; the molecules are over forty feet in diameter; and we are inside one of them. Without the use of a special equilibrator we could not survive the violent darting and stopping of the molecule. Even with the best adjustment of this device we feel some discomfort from the jerking motions, but you mustn't expect Pullman springs on atomic journeys.

As we look about us, swaying in the midst of this forty-foot molecule, we can have no realization of how far the region is beyond the spaces and forces from which we embarked. Every dimension here is fifty billion times what it is in human life. All measurement is so stretched that a ten-foot pole would reach almost from the earth to the sun. And still we are not able to see much of the skeleton of a molecule. In fact, unless I work magic for you and shock every sober-minded scientist, you will see nothing whatever. You will find yourself in a void. Strange forces will be tugging at you as if to rend an unwelcome visitor apart or crush him, but your eyes will peer in vain.

Here is a button that will show something. To touch it would be profanation for a physicist, but tourists enjoy the effect.

Click.

Around us flash circles of light, very thin lines of exceeding

brilliance, like threads of lightning. These sights within a molecule will be a maze of mystery unless we see a sketch-map of the surroundings before examining them in detail. What we are looking at is the three atoms that make up the molecule of water. The middle one of the three is an atom of oxygen, near the center of which we are floating; and at opposite sides of this are two atoms of hydrogen that are closely linked to it. The atoms are mostly empty space. The brilliant blur of light directly overhead, too close for comfort, is the "nucleus" at the center of the oxygen atom; and the set of six circles of light, twenty feet from us, is its surface. The two seven-foot circles of light beyond the oxygen atom, and on either side of it, are the surfaces of the two hydrogen atoms.

There is no sound, no odor, no variation in the dazzling loops. However erratic may be the motions of the whole molecule through space, within it there is no slightest variation of the absolute fixity of the glittering circles. And there is nothing else to see or touch within it.

There is no way to have any further view of the structure of water unless we enlarge the dimensions once more by a thousand times. The one-eighth-inch drop with which we started will then be a sphere of a greater diameter than the distance from the earth to the sun.

So—we have reached the limit of our journey.

3. THE WONDERS OF WATER

If you feel levity at such prodigious magnifying, you will never have an inkling of what modern chemistry is. If you have any suspicion that I am stretching the hard facts now known to students of the atom, dismiss it. All that I have done in these five stages of enlargement is to put into concrete

form what a Bragg [1] or a Lewis [2] means when he sets on paper the harmless-looking formula: "Hence the radius is 1.9×10^{-8} cms." When the first investigator saw an exponent $^{-8}$ as the result of his calculations, he was more incredulous than you can be about my trip on a magic carpet into Molecule Land. The smallness is comically beyond our comprehension. But it stands as a fact. A hundred emulous specialists have yearned to gain fame by proving it erroneous, yet every one of them assures us of its undoubted truth. If we wish to have any glimpse of modern notions about the nature of water, we must accept this enlargement of a drop as a plain and literal voyage to the facts.

Our molecule of water is now eight miles in diameter. In planning to arrive at this great size I was not wanton. Even this size, as you will shortly see, is too small to reveal one of the elements of the molecule, *about which physics has some accurate information.* If you now feel any humor or skepticism, you may take a nap until the party is ready to return home.

As you look about in this eight-mile molecule, you are disappointed. For nothing new is in sight. The thousand-times-larger loops are seen to be at a much greater distance, but they are still fine lines. Nothing else has come into view. In order to reveal the nature of the loops I must use another device of non-scientific magic, which I will call a slow-motion telescope. When you look through this at one of the circles of light, you perceive that it is formed by a glowing ball which revolves so rapidly that its circuit appears to the unaided eye as a continuous path of light.

[1] Sir William Henry Bragg (1862-). A British physicist, in 1915 winner of the Nobel prize in physics.

[2] Gilbert N. Lewis (1875-). An American chemist, author of *Valence and the Structure of Atoms and Molecules* (1923).

I dislike to tell about its speed, for no astronomer can comprehend it, and only a mathematician can credit it. The figure which states it is so huge that it is meaningless. If the ball revolved only ten times a second, its path would appear as an unbroken streak. A thousand times a second would seem the guess of a disordered brain. But that number is only one trillionth of what the strictest physicist certifies to us. He declares without a quiver that each one of the ten globes whirling in this one molecule of water is revolving a quadrillion times every second. Even that is an understatement, because I have, for the sake of brevity, thrown away a little factor of 6.5, which you are entitled to use if you ever get back to the humdrum world again and want to tell big stories.

As for me, I cannot credit any such number. I hope that within a few years some experiment will show that it is a blunder. It seems so inanely vast as to bring suspicion upon the facts in the rest of the atomic theory.

The whirling globes are named "electrons." Thanks to the labors of mathematicians who have never been on magic carpets, we know that electrons are, *in our eight-mile molecule,* only eight inches in diameter. Pardon me if I remind you what this means in the place where we now are: here, in a sphere that is almost a hundred million miles in diameter, an electron is only eight inches in diameter. Yet modern science has calculated its size and mass.

If we ask what it is made of, we can get no answer. Science knows only that it is a center of electrical force, and calls this force a unit of negative electricity. So here, at the uttermost limit of a fantastically huge enlargement, we come upon nothing but a mystery that is still remote from us, hidden far within another reach of endlessly decreasing dimensions. We can see nothing whatever of the interior of the electron. It may con-

tain so elaborate a mechanism that if we increased it yet another billion times we might come only to further mysteries at its core.

As a relief from such bewildering speculation about the infinitesimal, let us fly through the miles of space to that point at the boundary of the molecule where we see an electron revolving in its orbit. It is pleasant to feel the vast roominess of a molecule while we take a four-mile excursion to its surface. The electron is the only visible part of an atom of hydrogen. It is speeding steadily about a center that is more than a mile from it, at a rate of—I will not trouble you with the figures. Perhaps you will find it amusing to reckon its magnified speed from the actual rate of an electron in an actual atom of the eighth-of-an-inch drop—1300 miles a second. But don't tell Einstein [3] your result, for he does not permit anything to travel faster than light. The proportional speeds demanded in our magnified space are impossible.

The center around which the electron revolves is too small to be visible. After all our enlarging, hoping to spread out the distances till we could have a fair view of atoms, the central element of hydrogen is less than a hundredth of an inch in diameter. Even in our fearfully over-magnified molecule we must use a telescope to see the nucleus of the atom. It is called a "proton." It is dark in color. Though it is a thousand times smaller than its electron, it is nearly two thousand times as heavy. It is a unit of positive electricity, balanced against the unit of negative electricity in its electron. In its somber heaviness lies almost the entire mass of the hydrogen atom, and the chemical properties of the atom.

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[3] Albert Einstein (1879-). A German-Swiss physicist who set forward, in 1905, the theory of "relativity." He said that nothing can travel faster than light.

All that science can discern in this atom is these two opposite charges of electricity, one of which rotates about the other. No "matter," as we know it, is to be seen. An atom of hydrogen is a compound of a great deal of space and two extremely small pellets of electricity.

On the other side of the eight-mile molecule is another atom of hydrogen. These two atoms are attached, in some kind of close union, to the atom of oxygen which is between them. If an electric current were passed through the drop, we should see a separation of the atoms in all the molecules. The hydrogens would be detached and would link themselves in pairs; the oxygens would do likewise; and each pair of atoms would try to get as far as possible from every other pair. Thus two expanding gases would be formed.

If the drop were heated, the motions of its molecules would be increased; at its surface the molecules would be driven off, as water, in a gas—that is, as water-vapor, or steam.

If sufficient heat were withdrawn from the drop, we should see the molecules cease their disorderly knocking about and jump to position like so many soldiers at a command. They would form up in crystals, placing themselves in such a way as to occupy somewhat more space—and then the water would be frozen, expanded into ice.

Thus an atom is, in its outward relations, as fickle as a glancing color on foaming waves. But inwardly it is changeless. The orbit of its electron, to be sure, may be frequently altered through an indefinite number of stages; its electron *could* be separated from it altogether and the atom disintegrated. But the chances are that this particular atom of hydrogen has persisted since the earth was formed and will persist from everlasting to everlasting. If it were thrown out into the absolute zero of cold, or plunged into the heat of the sun, or

subjected to the extreme of pressure in a dense star—in every vicissitude its electron would continue to revolve. Its "shell" of force would be uninjured. An atom is an enduring, immaterial sphere that cannot be invaded or crushed. Within it are some unseen girders that withstand all violence; about it is some armor of impenetrable electricity.

The atom of hydrogen is the simplest known—one electron revolving about one proton. This is a sort of unit of structure for all the other chemical elements. An "element" is a distinct species of matter, a simple type, formed by the massing together of atoms of one kind. Hydrogen is an element; so is oxygen; so is iron, or mercury, or radium. But water is not an element; it is a "compound." Only 92 elements have been discovered or predicted in the universe, and the only difference that science can yet detect between them is the number of protons in the nucleus. In the nucleus of oxygen there are 16 protons, in the nucleus of iron 56, in mercury 200, in radium 226.

If we now return to the middle of the molecule, we can understand what we see, though its details are obscure. We are at the heart of the atom of oxygen. Clustered close together are 16 of the dark, heavy protons, each of which is a charge of positive electricity. About them and close to them is a blur of light caused by 8 electrons. We may be sure that the arrangement is not haphazard, for the oxygen atom is the most common one in the world, most adaptable for building all manner of compounds, most firmly constructed. It appears to be in four segments that are united in a peculiarly staunch way. Each segment is composed of 4 protons and 2 electrons. Thus the whole nucleus has 16 protons and 8 electrons. Electrically it is positive, for it contains twice as many positive units as negative ones.

The electrical balance of the whole atom is secured by 8 other electrons which revolve about the nucleus. Two of these are at a relatively short distance; 6 are at the outside of the atom, forming its "shell." The entire atom is four-square in structure and electrically neutral.

This intricate atom of oxygen, united in a complex manner with two atoms of hydrogen, is a molecule of water. Perhaps, after your attention has been so long confined to this elaborate domain, you are forgetting that it is only *one* molecule.

On every side, thudding against us in a perpetual game of volley-ball, are other molecules. Their eight-mile shells fill all the space in every direction. They are close-packed throughout this sphere that is a hundred million miles in diameter. If you are curious about how many there are, set down the figure five and write twenty ciphers after it. The most reckless estimate of the total of all the stars in all the galaxies of the universe would be insignificant compared with this number of molecules.

We say that a drop of water is "filled" with molecules. But science cannot detect any substance that does the filling. Matter, as we conceive it, occupies only one trillionth of one per cent of the space in water—and even that matter appears to be nothing but force. A drop of water is only a place where electricity is aggregated in certain combinations. Into these bunches of force science has penetrated with more sureness than is possible for tourists on a fairy-story contrivance.

Every particle of matter large enough to be seen is composed of quadrillions of regions of electrical energy. This is true of every little speck of cement or rust or wood or flesh. Every millionth of an inch of the progress of my voice over a telephone wire is engineered by millions of these regions of

force, which dance in exact accordance with my lightest whisper. And each one of the regions is a complication of secrets that are quite unfathomable.

4. THE RETURN TO ORDINARY LIFE

I will now bring you back from the interior of a drop of water with one brief remark: there are witty persons who consider atoms a dull, non-cultural subject.

For this rudeness of mine I offer no apology. If it is a painful way of returning to common life, it is wholesome. It will reveal to my guests on the magic carpet the difference between literary wit and scientific imagination—a difference which every citizen ought to understand nowadays.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 READY FOR ADVENTURE

1 Why does the first paragraph arouse interest?
2 On what plan is the article founded?
3 What is the purpose of the first section of the article?

2 ON THE SURFACE AND WITHIN

4 How does Mr. Ward make the narrative appeal to us as true to the ordinary facts of life?
5 What characteristic of a drop of water first awakens our wonder?
6 What enlargements of a drop of water does Mr. Ward suggest in order to lead his readers to clear understanding and also to appreciation?
7 Explain the interior of a drop of water.
8 Explain the nature of a molecule.
9 How does Mr. Ward make us realize the almost unbelievable smallness of atoms?
10 Explain the various characteristics noticed during the five stages of the journey into "Molecule Land."
11 How much of the article is truth, and how much is fiction?

3 The Wonders of Water

12 What are electrons?
13 How rapidly do electrons move?
14 Explain the nature of a proton.
15 What is the relative size of a proton?
16 Explain the relation between a proton and an electron.
17 What forms an atom of hydrogen?
18 What happens when a strong current of electricity passes through water?
19 What happens when water is heated?
20 What happens when water is cooled?
21 What is the "length of life" of an atom?
22 How are the atoms of various elements different from one another?
23 What is an element?
24 What is the number of elements?
25 Describe an atom of oxygen. How does it differ from an atom of hydrogen?
26 Summarize what is said about the structure of a drop of water.
27 What is the ordinary definition of "matter"? What is the scientific definition of "matter"?
28 How much "matter," in the ordinary sense of the word, is there in a drop of water?
29 Why did Mr. Ward write the article in the narrative form?

4 The Return to Ordinary Life

30 Explain the purpose of the last section of the article.

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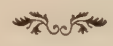
A NEW LIGHT IN THE WORLD

By

WILLIAM HENRY MEADOWCROFT

Reprinted from THE BOY'S LIFE OF EDISON, *by William H. Meadowcroft, Harper and Brothers, Publishers.*



"If among Edison's numerous inventions there should be selected one or a class that might be considered the greatest, it seems to be universal opinion that the palm would be awarded to the incandescent lamp and his complete system for the distribution of electric light, heat, and power."

WILLIAM HENRY MEADOWCROFT.

WILLIAM HENRY MEADOWCROFT
(1853-)

As Assistant and Confidential Secretary to Thomas A. Edison since 1910, Mr. William H. Meadowcroft knows Mr. Edison as few others know him. *The Boy's Life of Edison,* from which the chapter, *A New Light in the World,* is taken, is an intimate account of the life and work of the great inventor, published with the full consent of Mr. Edison.

Mr. Meadowcroft is a student of electricity and a successful inventor. He was one of the first experimenters with X-rays and liquid air, and he developed the use of small electric lamps and display electric signs.

Mr. Meadowcroft is the author of *The A B C of Electricity* (1888); *The A B C of the X-ray* (1897); and *The Boy's Life of Edison* (1911); and he aided in the writing of *Edison—His Life and Inventions* (1911) by Frank Lewis Dyer and T. Commerford Martin.

A NEW LIGHT IN THE WORLD

By William Henry Meadowcroft

I. SUGGESTIONS FOR ELECTRIC LIGHT

IN THESE modern times an incandescent electric lamp is such an every-day affair as to be a familiar object even to a small child. But only a few years ago—a little over thirty—the man who proposed and invented it was derided in the newspapers, and called a madman and a dreamer.

If among Edison's numerous inventions there should be selected one or a class that might be considered the greatest, it seems to be universal opinion that the palm would be awarded to the incandescent lamp and his *complete system* for the distribution of electric light, heat, and power. These inventions as a class, and what has sprung from them, have brought about most wonderful changes in the world.

The year 1877 was a busy one at Edison's laboratory at Menlo Park. He was engaged on the telephone, on acoustic electrical transmission, sextuplex telegraphs, duplex telegraphs, miscellaneous carbon articles, and other things. He also commenced experimenting on the electric light.

Besides, he invented the phonograph. The great interest and excitement caused by the latter invention took up nearly all of his time and attention for many months, and, indeed, up to July, 1878. He then took a vacation and went out to Wyoming with a party of astronomers to observe an eclipse of the sun and to make a test of his tasimeter.[1]

[1] Tasimeter. An ingenious apparatus to detect changes in electrical pressure.

He was absent about two months, coming home rested and refreshed. Mr. Edison says: "After my return from the trip to observe the eclipse of the sun I went with Professor Barker, professor of physics in the University of Pennsylvania, and Dr. Chandler, professor of chemistry in Columbia College, to see Mr. Wallace, a large manufacturer of brass in Ansonia, Connecticut. Wallace at this time was experimenting on series arc lighting. Just at that time I wanted to take up something new, and Professor Barker suggested that I go to work and see if I could subdivide the electric light so it could be got in small units like gas. This was not a new suggestion, because I had made a number of experiments on electric lighting a year before this. They had been laid aside for the phonograph. I determined to take up the search again and continue it. On my return home I started my usual course of collecting every kind of data about gas; bought all the transactions of the gas engineering societies, etc., all the back volumes of gas journals, etc. Having obtained all the data, and investigated gas-jet distribution in New York by actual observations, I made up my mind that the problem of the subdivision of the electric current could be solved and made commercial."

2. THE WORK OF EARLY EXPERIMENTERS

The problem which Edison had undertaken to solve was a gigantic one. The arc light was then known and in use to a very small extent, but the subdivision of the electric light —as it was then called—had not been accomplished. It had been the dream of scientists and inventors for a long time.

Innumerable trials and experiments had been made in America and Europe for many years, but without success. Although a great number of ingenious lamps had been made

by the foremost inventors of the period, they were utterly useless as part of a scheme for a system of electric lighting. In fact, these efforts had been so unsuccessful that many of the leading scientists of the time, even as late as 1879, declared that the subdivision of the light was an impossibility.

The chief trouble was that the early experimenters did not conceive the idea of a *system,* and worked only on a lamp. They all seemed to have the idea that an electric lamp was the main thing and that it should be of low resistance and should be operated on a current of very low voltage, or pressure. They, therefore, experimented on lamps using short carbon rods or strips for burners, which required a large quantity of current.

Electric lighting with this kind of lamp was indeed a practical impossibility. The quantity of current required for a large number of them would have been prodigious, giving rise to tremendous problems on account of the heating effects. Besides, the most fatal objection was the cost of copper for conductors, which for a city section of about half a mile square would have cost not less than a hundred million dollars, on account of the enormous quantity of current that would be required.

Mr. Edison realized at the beginning that previous experimenters had failed because they had been following the wrong track. He knew that electric lighting could not be a success unless it could be sold to the public at a reasonable price and pay a profit to those who supplied it. With such lamps as had been proposed, requiring such an enormous outlay for copper, this would have been impossible. Besides, there would not have been enough copper in the world to supply conductors for one large city.

Edison did what he has so often done before and since.

He turned about and went in the opposite direction. He reasoned that in order to develop a successful system of electric lighting the cost of conductors must come within very reasonable limits. To insure this, he must invent a lamp of comparatively high resistance, requiring only a small quantity of current, and with a burner having a small radiating surface.

3. EDISON'S FIRST EXPERIMENTS

Having the problem clearly in mind, Edison went to work in the fall of 1878 with that enthusiastic energy so characteristic of him. His earliest experiments were made with carbon as the burner for his lamp. In the previous year he had also experimented on this line, beginning with strips of carbon burned in the open air, and then *in vacuo* by means of a hand-worked air-pump. These strips burned only a few minutes. On resuming his work in 1878 he again commenced with carbon, and made a very large number of trials, all *in vacuo*. Not only did he try ordinary strips of carbonized paper, but tissue-paper coated with tar and lampblack was rolled into thin sticks, like knitting-needles, carbonized and raised to the white heat of incandescence *in vacuo*.

He also tried hard carbon, wood carbon, and almost every conceivable variety of paper carbon in like manner. But with the best vacuum that he could then get by means of the ordinary hand-pump the carbons would last at the most only from ten to fifteen minutes in a state of incandescence.

It was evident to Edison that such results as these were not of commercial value. He feared that, after all, carbon was not the ideal substance he had thought it was for an incandescent lamp-burner. The lamp that he had in mind was one which should have a tough, hair-like filament for a light-giving body

that could be maintained at a white heat for a thousand hours before breaking.

He therefore turned his line of experiments to wires made of refractory metals, such as platinum and iridium, and their alloys. These metals have very high fusing points, and while they would last longer than the carbon strips, they melted with a slight excess of current after they had been lighted but a short time.

Nevertheless, Edison continued to experiment along this line, making some improvements, until about April, 1879, he made an important discovery which led him to the first step toward the modern incandescent lamp. He discovered that if he introduced a piece of platinum wire into an all-glass globe, completely sealed and highly exhausted of air, and passed a current through the platinum wire while the vacuum was being made the wire would give a light equal to twenty-five candle-power without melting. Previously, the same length of wire would melt in the open air when giving a light equal to four candles.

He thus discovered that the passing of current through the platinum while the vacuum was being obtained would drive out occluded gases (*i.e.* gases mechanically held in or upon the metal). This was important and soon led to greater results.

Edison and his associates had been working night and day at the Menlo Park laboratory, and now that promising results were ahead their efforts went on with greater vigor than ever. Taking no account of the passage of time, with an utter disregard of meal-times, and with but scanty hours of sleep snatched reluctantly at odd periods, Edison labored on, and the laboratory was kept going without cessation.

Following up the progress he had made, Edison made im-

provement after improvement, especially in the line of high vacua, and about the beginning of October had so improved his pumps that he could produce a vacuum up to the one-millionth part of an atmosphere. It should be understood that the maintaining of such a high vacuum was only rendered possible by Edison's invention of a one-piece all-glass globe, hermetically sealed during its manufacture into a lamp.

In obtaining this perfection of vacuum apparatus Edison realized that he was drawing nearer to a solution of the problem. For many reasons, however, he was dissatisfied with platino-iridium filaments for burners, and went back to carbon, which from the first he had thought of as an ideal substance for a burner.

His next step proved that he was correct. On October 21, 1879, after many patient trials, he carbonized a piece of cotton sewing-thread bent into a loop or horseshoe form, and had it sealed into a glass globe from which he exhausted the air until a vacuum up to one-millionth of an atmosphere was produced. This lamp, when put on the circuit, lighted up brightly to incandescence and maintained its integrity for over forty hours, and lo! the practical incandescent lamp was born. The impossible, so called, had been attained; subdivision of the electric current was made practicable; the goal had been reached, and one of the greatest inventions of the century was completed.

Edison and his helpers stayed by the lamp during the whole forty hours watching it, some of the men making bets as to how long it would burn. It may well be imagined that there was great jubilation throughout the laboratory during those two days of delight and anxiety.

But now that the principle was established work was renewed with great fervor in making other lamps. A vast

number of experiments were made with carbons made of paper, and the manufacture of lamps with these paper carbons was carried on continuously. A great number of these were made and put into actual use.

4. IMPROVING THE ELECTRIC LAMP

Edison was not satisfied, however. He wanted something better. He began to carbonize everything that he could lay hands on. In his laboratory note-books are innumerable jottings of the things that were carbonized and tried, such as tissue-paper, soft paper, all kinds of cardboards, drawing paper of all grades, paper saturated with tar, all kinds of threads, fish-line, threads rubbed with tarred lampblack, fine threads plaited together in strands, cotton soaked in boiling tar, lamp-wick, twine, tar and lampblack mixed with a proportion of lime, vulcanized fiber, celluloid, boxwood, cocoanut hair and shell, spruce, hickory, baywood, cedar, and maple shavings, rosewood, punk, cork, bagging, flax, and a host of other things.

He also extended his searches far into the realms of nature in the line of grasses, plants, canes, and similar products, and in these experiments at that time and later he carbonized, made into lamps, and tested no fewer than six thousand different species of vegetable growths.

At this time Edison was investigating everything with a microscope. One day he picked up a palm-leaf fan and examined the long strip of cane binding on its edge. He gave it to one of his assistants, telling him to cut it up into filaments, carbonize them, and put them into lamps.

These proved to be the best thus far obtained, and on further examination Edison decided that he had now found the

best material so far tried, and a material entirely suitable for his lamps.

Within a very short time he sent a man off to China and Japan to search for bamboo, with instructions to keep on sending samples until the right one was found. This man did his work well, and among the species of bamboo he sent was one that was found satisfactory. Mr. Edison obtained a quantity of this and arranged with a farmer in Japan to grow it for him and to ship regular supplies. This was done for a number of years, and during that time millions of Edison lamps were regularly made from that particular species of Japanese bamboo.

Mr. Edison did not stop at this, however. He was continually in search of the best, and sent other men out to Cuba, Florida, and all through South America to hunt for something that might be superior to what he was using. Another man was sent on a trip around the world for the same purpose.

Some of these explorers met with striking adventures during their travels, and all of them sent vast quantities of bamboos, palms, and fibrous grasses to the laboratory for examination, but Edison never found any of them better for his purposes than the bamboo from Japan.

In this remarkable exploration of the world for such a material will be found an example of the thoroughness of Edison's methods. He is not satisfied to believe he has the best until he has proved it, and this search for the best bamboo was so thorough that it cost him altogether about one hundred thousand dollars.

In the meantime he was experimenting to manufacture an artificial filament that would be better than bamboo. He finally succeeded in his efforts, and brought out what is known as a "squirted" filament. This was made of a cellulose mix-

ture and pressed out in the form of a thread through dies. This kind of filament has gradually superseded the bamboo in the manufacture of lamps.

We have been obliged to confine ourselves to a very brief outline history of the invention and development of the incandescent lamp. To tell the detailed story of the intense labors of the inventor and his staff of faithful workers would require a volume as large as the present one.

All that could be done in the space at our disposal was to try to give the reader a general idea of the clear thinking, logical reasoning, endless experimenting, hard work, and thoroughness of method, of Edison in the creation of a new art.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 Suggestions for Electric Light

1 Why do we wonder so little at many of our most useful inventions?
2 Name and explain some of the changes that have been brought about through the use of electric lighting.

2 The Work of Early Experimenters

3 What difficulties confronted Mr. Edison when he began his efforts to devise successful electric lighting?
4 Explain the errors made by some of the early experimenters with electric lighting.
5 How did Mr. Edison solve the problem of electric lighting?

3 Edison's First Experiments

6 Explain Mr. Edison's first experiments in connection with electric lighting.
7 By what means did Mr. Edison win success?

4 Improving the Electric Lamp

8 What shows Mr. Edison's persistence and patience in carrying on his work?

9 What slight incident led to the final results?
10 To what lengths did Mr. Edison go in order to carry on experiments in connection with electric lighting?
11 Why was Mr. Edison willing to spend so much time, effort, and money in his investigations?
12 Summarize the characteristics that are necessary to success in scientific work.
13 Tell about any investigations or experiments that you yourself have carried on.

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ELECTRICITY AND CIVILIZATION

By

CHARLES PROTEUS STEINMETZ

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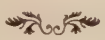

"It is the characteristic of electric energy that it can be distributed and converted into any other form of energy in a very simple and highly efficient manner."

CHARLES P. STEINMETZ.

CHARLES PROTEUS STEINMETZ
(1865-1923)

One of the greatest of modern students of electricity and mathematics, Charles Proteus Steinmetz, Consulting Engineer of the General Electric Company, Schenectady, New York, and Professor of Electro-Physics in Union University, Schenectady, devoted himself to applying science to industry.

Of German birth, Mr. Steinmetz came to the United States at the age of 24, and soon took a commanding position as electrical engineer. With no desire whatever to use his great ability for the making of money, he gave himself entirely to the scholarly work that held him fascinated.

Among his books are *Theory and Calculation of Alternating-Current Phenomena* (1897); *Theory and Calculation of Transient Electric Phenomena and Oscillations* (1909); *Radiation, Light and Illumination* (1909); *Engineering Mathematics* (1910); *Electric Discharges, Waves and Impulses* (1911); *America and the New Epoch* (1916); *Theory and Calculation of Electric Circuits* (1917); *Theory and Calculation of Electrical Apparatus* (1917).

ELECTRICITY AND CIVILIZATION

By Charles Proteus Steinmetz

I. OUR INDEPENDENCE OF SURROUNDINGS

THE chief characteristic of our age is man's independence of his immediate surroundings. The savage necessarily must depend upon his immediate neighborhood for the necessities of life. Some barter and commerce developed during the barbarian ages, but in the absence of any efficient means of transportation, even up to fairly recent times, such commerce could deal with luxuries and rare articles only, but for the common necessities of life man was still dependent on his immediate surroundings, and a local crop failure meant famine and starvation.

The great French Revolution at the end of the eighteenth century made man politically free, changed him from a serf to a citizen; and so unfettered the ability, initiative, and ambition of all. The invention of the steam engine advanced man from a machine doing the mechanical labor of the world to a machine tender, directing the machines capable of doing the work of thousands of men, and set him mechanically free. The higher intelligence and knowledge required for this demanded education of the masses of the people, and so gave them an intellectual freedom which the illiterate man of former ages could not have possessed.

Thus came the great and rapid development of our modern industrial and engineering civilization, which is characterized by the almost complete independence of man of his surround-

ings. No matter where we live, whether in the center of the great metropolis, or in a small village far out in the wilderness, anything that man and earth produce anywhere, is available to us; the mail takes the order at our house, and in due time, by steamship and railway train, by express company or mail, it is delivered at our house.

This development of the means of transportation of materials by the steamship lines which cover the oceans, the railways which cover the continents with a network of tracks, the system of express and mail service, has been the great achievement of the nineteenth century, the foundation of our civilization, as we are forcibly made to realize whenever the transportation system breaks down in the slightest degree.

2. THE TRANSPORTATION OF ENERGY

But civilization depends on two things—materials and energy. As vitally important as materials, from the necessities of life to its luxuries, is energy, or power, as we often call it. That is, the thing which makes the wheels go around, which drives the factories and mills, which in the steam locomotive carries us far better and faster than our feet could; which, in the rays of the electric light or the gas flame, lights our homes and turns night into day; which, in the heat of coal burning in the stove, warms our houses and makes our climate inhabitable, and in our homes fetches and carries, cools the air by the fan motor or cooks our food, drives the sewing machine or the ice-cream freezer, sweeps and dusts by the vacuum cleaner, washes, irons, and does more and more of the manual labor, and can and will do still more in the future to make life agreeable and efficient.

But while the methods of supply, transportation, and dis-

tribution of materials have been developed highly by the transportation systems, which were the great work of the last century, we are still backward in the energy supply for the needs of man; and this is the present great limitation of our civilization which the engineer is endeavoring to overcome.

We cannot make or create energy. Thus, we have to take it from where we find it in nature, and bring it where we need it. The two big stores of energy in nature are in the coal mine and the waterfall, the former supplying the chemical energy of fuel (coal, oil, natural gas, etc.), which is set free as heat energy by combustion, and the latter supplying the hydraulic or mechanical energy.

The first problem which we meet, then, is how to transport the energy from its source to the place where we need it. We can do this well enough with the chemical energy of coal, by carrying the coal in railway train or steamship, and so we are doing, though it is rather an inefficient way, as it costs more to bring the coal from the mine to the consumer than it does to mine it. But mechanical energy, as the hydraulic energy of water power, we cannot transport as such at all (or "transmit," as we usually term the transportation of energy), and before the advent of electrical energy transmission the water powers were practically useless. The only way was for the user of energy to locate at the water power. But the place where the water power is found is rarely suitable for an industry, hardly ever for a big city, and these are the two largest users of energy. It was the electrical engineer who made the water powers of use, by changing, "transforming" the hydraulic energy of the waterfall into electric energy, to send it over the electric transmission line to the distant places where energy is needed, and distribute it as electric energy.

3. FUEL ENERGY VS. ELECTRICAL ENERGY

There are only two kinds or forms in which energy can be economically carried over long distances, "transported" or "transmitted"—as the chemical energy of fuel by the railway car or steamship, and as electrical energy by the transmission line; and when from your train window you see the coal cars going by or the electric transmission lines flying past, you realize that both fulfil the same function, carrying the energy —that is, the power of doing things, on which our civilization depends, from its source where it is found in nature to the place where we need it.

But, while fuel energy and electrical energy both can be economically transported or transmitted, there is a vast difference in them when we arrive at the destination and meet the problem of distributing and transforming the energy into that form which we need—heat energy to warm our homes and cook our food; light energy to extend the hours of daylight; mechanical energy to fetch and carry, to bring us to and from our work or pleasure, to turn the wheels of industry, drive the motor, whether the small fan motor of a fraction of a cat's power which cools our room, or the giant motor in the steel mill, which with the power of ten thousands of horses squashes steel ingots of tons of weight, as though they were soft putty, into the shape of rails to carry the train, or steel beams to support our building structures, or span the rivers as bridges.

We can change the chemical energy of fuel into heat by burning it in our stoves and furnaces in a fairly simple, though rather inefficient, manner.

But when we wish to convert the fuel energy into mechanical power we can do it efficiently and economically only in

very large units, in the huge and highly complicated steam-turbine stations of ten thousands or hundred thousands of horse power; and we cannot mechanically distribute this energy except in a highly wasteful and inefficient manner, by shafts and belts and countershafts.

If we want light, we have to select special fuels, as kerosene, or first convert the fuel energy of coal into that of gas in gas works, and distribute the gas; and even then we are far from the convenience and cleanliness of the electric light.

It is the characteristic of electric energy that it can be distributed and converted into any other form of energy in a very simple and highly efficient manner, and that the economy of distribution and conversion is practically the same, whether we want the minute amount of energy to ring our door bell, or the power of hundred thousands of horses to drive the propellers of the battle cruiser.

I press the button, and the electric light flashes up; I close the switch, and the fan motor starts at my desk, or the elevator begins to move, carrying tons of load, or the giant electric locomotive starts pulling the thousand-ton train. And there is little difference in the efficiency of the small motor driving a sewing machine and the giant motor on the rolling mill of the steel plant: either gives in mechanical power practically the full amount of the electric power which it receives.

Electrical energy is unique in this respect, and it is the only form of energy which can be transmitted, distributed, and converted into any other form of energy with high efficiency —that is, with losses which are almost negligible, in the simplest possible manner and with practically no attention: closing the switch starts it, opening the switch again stops it, and that equally well and efficiently for the most minute power as for the largest amounts of power.

Electrical energy thus is the form of energy best suited for the transmission and supply of the world's demand for energy, is indeed the only form of energy capable of doing this; and when you see the electric transmission lines criss-crossing the country and spreading over it in a network of wires, just as during the last century the railways spread their network of tracks over the country, you should realize that the electrical engineer is doing to-day for the world's energy supply what the railway engineer did during the last century for the world's material supply—he is organizing the world's energy supply required to complete and maintain our civilization.

Thus, electric energy is the most useful form of energy, and at the same time it is the most useless; it is not found in nature in usable quantity; the electrical energy of the lightning flash is too erratic and too small in amount to make it worth while to collect it, even if it could be done, and all electric energy is produced by conversion from some other form of energy —mechanical in the generator, chemical in the battery. Electric energy is never used as such (except in minute amounts occasionally medicinally), but when used, it is always first converted into some other form of energy. Thus, electrical energy is the intermediary in the problem of taking some form of energy from somewhere and delivering it as some other form of energy somewhere else. Electric energy is the only energy fitted for this function as intermediary, as carrier between the source and the user of energy, due to its ease, simplicity, and efficiency of production from other forms of energy and conversion into other forms of energy, and the efficiency and economy of its transmission.

Thus, with the rare exception where a power user can locate at the waterfall, water powers are always converted into elec-

trical energy and transmitted and distributed as such, and it was the development of electrical engineering which has opened up to the uses of man in the water powers, the second largest source of energy. The chemical energy of fuel, from coal mine, oil well, or gas well, is still usually transmitted or transported as chemical energy by railway train or steamship line. The proposition has been made and discussed to burn the coal at the mine under steam boilers, convert its energy into electrical energy, and transmit it as such. To some extent, at least, this will undoubtedly be done in the future, as the major part of the cost of coal is not its mining, but its transportation, and, besides, a considerable part of the coal taken out of the mine is wasted by being so poor and mixed with dirt that it cannot be economically transported; it could, however, be burned in proper furnaces at the mine, and so made useful as electrical energy. The extent, however, to which we could hope to do this is limited by the limitation of the steam engine. The steam engine requires not only fuel to produce the steam, but also large amounts of water to condense the steam, and very often such condensing water is not available at the coal mine.

But, while most of the fuel energy is still transmitted or transported as such, when it comes to the distribution of energy, more and more the electrical form of energy is used. That is, in a big electric station near the demand of power—the big city, mill, or factory—the fuel energy is converted into electrical energy, and distributed as such. We could distribute and deliver the energy as fuel—coal, oil, or gas—but what then? There is no simple and efficient way to convert the energy of coal, etc., into mechanical energy to propel the trolley car, or drive the sewing machine, into light to light our homes, etc., such as is afforded by the electric power. The

difference in the usefulness of electrical energy in deriving any other form of energy from it, compared with the energy of coal, is best illustrated by such a simple convenience as the electric fan—push the button, and the fan starts; push it again, and it stops. Now imagine the problem of operating your desk fan by means of the energy of coal; you have attached to the fan a little steam engine, and to it a little boiler, and a little coal furnace, and when you want to start the fan you start a fire in the little furnace on your desk and get up steam in the little boiler, and operate the little steam engine to drive the fan. You see how impossible it is to use fuel energy for general energy distribution. You may say: "We should not use coal, but gas or oil, in a gas engine. We should have a little gas engine attached to our fan." This is simpler, but you fill your room with the ill-smelling hot exhaust gases, and, after all, to keep the gas engine running you have to have a magneto for ignition, and this is larger than the whole electric-fan motor. Or, if you use battery ignition, the power you take out of the battery could by a small electric motor drive your fan.

This illustrates the superiority of electric power in energy distribution, and so a whole new industry has grown up in the last twenty-five years—the industry of electric-power generation and distribution. From the small electric-lighting stations of the early days have grown up huge electric-power stations, some of them approaching a million horse power, and more and more supplying all the energy demand of the city or country, whether for lighting homes or streets, for driving the surface trolleys or the rapid-transit systems and the terminals of the steam railroads, supplying energy to factories and mills—in short, taking care of the energy supply and distribution.

In the field of rail transportation, the electric motor has superseded all other means, except the steam locomotive on our trunk-line railways. But every engineer who has looked into the situation knows that the steam locomotive is doomed by its frightful wastefulness, and electrification is inevitable. By electric operation of our railways, even if all the electric power were generated by steam and no water power used, we should save about two-thirds of the coal now consumed by the locomotives—that is, hundreds of millions of tons—and at the same time, without a single mile of additional track, increase the capacity of our railroads by a quarter or more, due to the quicker start, better control, and higher speed of the electric train.

In factories and mills the electric motor is replacing the steam engine, and thereby changing our industrial system. So we have seen in the last twenty-five years the cotton industry shifting from the New England states to the South, due to the economic advantage afforded by the abundant water powers of the Southern streams.

When, in changing to electric power, we replace the steam engine by the electric motor without any further change, this is rarely the more economical way, as the electric motor can do many things which the engine cannot do; and this permits a rearrangement of power supply, resulting in a great increase of economy. The steam engine is economical only in large units, and requires constant care and skilled attendance. Thus, it is not possible to place a small steam engine at every machine where power is wanted, but one big steam engine drives the factory, through numerous shafts and counter-shafts and masses of belts, in which quite commonly more than half of the power is wasted, even when the factory is running full; and the waste becomes still greater when the factory is

operated only partly, or when only a few machines have to be run for overtime work. The electric motor, however, whether large or small, requires practically no attendance. Thus, a separate motor may be attached to every machine, whether a sewing machine requiring a twentieth of a horse power or a mill motor of a thousand horse power. Thus all the shafting and belting disappear, light is let into the factory, and the safety vastly increased, and the enormous losses of power in the transmission saved. So also in transportation—the electric locomotive is more efficient than the steam locomotive, but more efficient still is the electric motor car, and, while steam trains have become larger and larger, to use the largest and most efficient locomotives, wherever possible, in electric traction individual motor cars are used, giving a more frequent and thus better service.

It therefore has been said, "To do a thing well and efficiently, do it electrically," and there is a great deal of truth in this.

4. HOUSEHOLD USES OF ELECTRICITY

In our households, and generally in everyday life, electricity is playing a larger and larger part.

Electricity is the only commodity which during the last twenty-five years has steadily decreased in price, due to the rapid advance of electrical engineering, and even in the last few years, when all other commodities doubled and tripled in cost, the price of electricity has hardly increased at all, so that domestic uses of electricity, which once were a luxury, now have become more economical than the old ways, besides being far more convenient, cleanly, and sanitary.

Thus, electricity is supplying household power and saving labor, eliminating the drudgery which formerly made house-

hold work so unattractive—fan motor and vacuum cleaner, the motor on the sewing machine or the ice-cream freezer, the washing machine and ironing machine, the doorbell, the electric flatiron; electric cooking, from special services, as electric toaster, coffee percolator, etc., to the electric range replacing the coal- or gas-fed cooking stove—in all these electricity has found its field. It is reasonable to expect that all the domestic and industrial work of the city, all locomotion and transportation, will some time be done by electricity, and that in a not very distant future, and that fires and combustion will be altogether forbidden by law within the city limits, as dangerous and unsanitary. It is not reasonable to believe that our civilized society will always allow the air and the sky above our cities to be filled with soot from a thousand smoke-belching chimneys, or the air of the city streets to be poisoned by the ill-smelling exhaust gases of thousands of gasoline cars, when electricity can perform the duty in a safer and better manner.

As we have seen, it is not the best economy, in industrial electrification, merely to take out the steam engine and put an electric motor in its place; but best economy requires a rearrangement, the elimination of the mechanical power distribution by shafts and belts, and putting an electric motor at every machine. So in domestic electrification it would be hopelessly uneconomical, even with the lowest prices of electricity, merely to replace the grate of the coal stove or the burner of the gas stove by an electric heater, due to the enormous waste of heat inevitable in the coal stove, and even gas stove. But electric heat can be employed so much more directly, and with so little loss, as to make electric cooking economical, and often even cheaper than cooking by coal or gas stove, though the heat from electric power must always

remain much more expensive than heat by the combustion of coal.

This is most marked in domestic heating. Suppose we take out the grate from our hot-air, steam, or hot-water-heating furnace in the cellar of our house, put in an electric heater and try to use the present heating plant; even at the lowest imaginable rate of electric power, the cost would be such as to make it economically hopeless. We get a better economy by putting an electric heater in every room; but still the cost of heating would inevitably be much greater than our present method, so that it could be used only in special cases, in the business centers of big cities, where the space occupied by the heating system is very valuable, or to heat some individual room, as a sick chamber or a bedroom, without the need of starting the entire heating plant—that is, as auxiliary to the coal furnace of to-day.

It is not possible that the cost of electric heat compared with that of coal can ever decrease sufficiently to make electric heating of our present houses generally economical. When electric energy is produced from coal, even in our most efficient huge steam-turbine stations, we get only 15 to 20 per cent of the energy of the coal, as electric energy, due to the inherent limitation of the steam engine. If, then, this electric energy is used for heating, the coal used in producing the electric energy costs five to six times as much as the coal which would produce the same amount of heat directly by combustion. The cost of the fuel is only a part, often less than half, of the cost of the electric energy, so that the actual cost of the heat produced from electricity in domestic service must be ten to twenty times as great as that of the cost of the same amount of heat produced by the burning of coal, and the price thus still higher. There is no possibility that cheap hydraulic power

could ever reduce the price of electricity so radically as to make the cost of electric heat comparable with that of heat from coal. Some people still believe that electricity from water power costs nothing, or very little, because no fuel is consumed in producing it; but the cost of fuel is only a part of the cost of electric power; a large part of the cost of power is the interest in development, and depreciation of the plant. Hydro-electric plants almost invariably cost several times as much as steam plants, due to the much more expensive and extensive hydraulic development, the cost of transmission lines, etc. Therefore, what is saved in the hydraulic station, in the cost of fuel, is in general pretty nearly lost in the higher cost of the development, with the result that electricity from water power can differ little in cost from that from steam power. That is, some water powers can produce electricity cheaper than the average steam station, and some large steam stations cheaper than the average water-power station, and in general hydro-electric power is a little cheaper and a little less reliable than steam-electric power, but the difference is not sufficient to give the water power any radical economic advantage.

We also must realize that if all the possible water powers were used—that is, every drop of rain which falls in the United States were collected and its power converted into electricity —and all this electric power used for heating, the total amount of heat produced would be only about one-third as much as that given by our present coal consumption.

Nevertheless, even with the present prices of electric energy for domestic purposes, electric house heating might be economically feasible. But it means an entire rearrangement of the heating and ventilating methods, even of the construction of our buildings, it means the "house without a chimney."

The walls of the house would be built insulated against

losses of heat by conduction through them; double or triple glass used in the windows; all the cracks and openings, through which cold air might enter, made perfectly tight; double or triple entrance doors used, not to lose appreciable heat when opening them—so it would be possible to reduce the present losses of heat to a small fraction. There remains the question of ventilation. Usually we let fresh—and cold—air in and the foul warm air out and so lose all the heat contained in the latter, and over and over again have to heat new volumes of cold air. With the expensive electric heat this is not permissible and is not necessary, but a regenerative system of ventilation is used. That is, the heat contained in the foul warm air which leaves the house is transferred to the fresh cold air entering it, and so heats it by the outgoing air passing around the pipes which carry in the fresh air. An air-tight house, and a regenerative system of ventilation would reduce the amount of heat required to keep our homes warm during the cold season to such a small fraction of the heat required with our present method of building construction that electric heating would become economical with the present price of electricity. Such a change, obviously, can only come gradually.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 Our Independence of Surroundings

1 What is the chief characteristic of our age?
2 What benefits followed the French Revolution?
3 Why did the invention of the steam engine advance civilization?
4 What accounts for the rapid development of our industrial and engineering civilization?

2 The Transportation of Energy

5 What advantages do we have that the people of former times did not have?

6 How important is the transportation system?
7 Why does civilization depend both on materials and on energy?
8 What needs of civilization are still to be supplied?
9 What are two great sources of energy?
10 How have we been able to utilize the energy produced by water power?

3 Fuel Energy vs. Electrical Energy

11 What are the relative advantages of the two forms in which energy may be transported economically?
12 Explain the loss that is experienced in converting fuel energy into mechanical power.
13 Why is electrical energy superior to fuel energy?
14 How does the electrical engineer aid civilization?
15 What is meant by saying that electrical energy is almost never used as such?
16 What use may the people of the future make of coal?
17 How does Mr. Steinmetz illustrate the simplicity of using electrical energy?
18 What new industries have been developed because of electricity?
19 Make a forecast for the railroads of the future.
20 What changes is electricity making in our industrial system?
21 In what ways does electricity take the place of steam?

4 Household Uses of Electricity

22 Why has the use of electricity in the household increased?
23 What changes in city life is electricity likely to make?
24 How may electricity affect health conditions?
25 Why is the use of electricity economical?
26 How will electricity affect the heating of the future?
27 What literary characteristics appear in the article?

BOOKS FOR FURTHER READING

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MODERN PHYSICS

By

ROBERT ANDREWS MILLIKAN

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"It is to lighten man's understanding, to illuminate his path through life, and not merely to make it easy, that science exists."

ROBERT ANDREWS MILLIKAN.

ROBERT ANDREWS MILLIKAN

(1868-)

For his work in isolating and measuring the electron, and for photo-electric researches, Robert Andrews Millikan, the distinguished American physicist, was awarded the Nobel Prize in Physics in 1923, and in the same year the Hughes Medal of the Royal Society of Great Britain. In addition he has been given various other distinguished awards, made member of many learned societies, and presented with many honorary degrees. His contributions to the advancement of exact science have been very great. To a marked degree Professor Millikan has the ability to work long, patiently and accurately, and to develop new and striking lines of investigation.

After his graduation from Oberlin Mr. Millikan studied in Columbia, Berlin, and Göttingen Universities. He taught physics in Oberlin two years, in the University of Chicago 25 years, and since 1921 has been Director of the Norman Bridge Laboratory of Physics in the California Institute of Technology.

Among his books are the following: *A Course of College Experiments in Physics* (1898); *Mechanics, Molecular Physics, and Heat* (1901); *A First Course in Physics* (1906); *A Laboratory Course in Physics for Secondary Schools* (1906); *Electricity, Sound, and Light* (1908); *The Electron* (1917); *Elements of Physics* (1917); *Science and Life* (1923); *Evolution of Science and Religion* (1927).

MODERN PHYSICS

By Robert Andrews Millikan

1. THE SPIRIT OF SCIENTIFIC RESEARCH

THE spirit of modern science is something relatively new in the history of the world, and I want to give an analysis of what it is. I want to take you up in an aeroplane which flies in time rather than in space, and look down with you upon the high peaks that distinguish the centuries, and let you see what is the distinguishing characteristic of the century in which we live. I think there will be no question at all, if you get far enough out of it so that you can see the woods without having your vision clouded by the proximity of the trees, that the thing which is characteristic of our modern civilization is the spirit of scientific research,—a spirit which first grew up in the subject of physics, and which has spread from that to all other subjects of modern scientific inquiry.

That spirit has three elements. The first is a philosophy; the second is a method, and the third is a faith.

2. THE PHILOSOPHY OF SCIENCE

Look first at the philosophy. It is new for the reason that all primitive peoples, and many that are not primitive, have held a philosophy that is both animistic [1] and fatalistic.[2] Every phenomenon which is at all unusual, or for any reason not

[1] Animistic. Believing in the influence of gods, demons, and spirits.
[2] Fatalistic. Believing that events are pre-determined.

immediately intelligible, used to be attributed to the direct action of some invisible personal being. Witness the peopling of the woods and streams with spirits, by the Greeks; the miracles and possession by demons, of the Jews; the witchcraft manias of our own Puritan forefathers, only two or three hundred years ago.

That a supine fatalism results from such a philosophy is to be expected; for, according to it, everything that happens is the will of the gods, or the will of some more powerful beings than ourselves. And so, in all the ancient world, and in much of the modern, also, three blind fates sit down in dark and deep inferno and weave out the fates of men. Man himself is not a vital agent in the march of things; he is only a speck, an atom which is hurled hither and thither in the play of mysterious, titanic, uncontrollable forces.

Now, the philosophy of physics, a philosophy which was held at first timidly, always tentatively, always as a mere working hypothesis, but yet held with ever increasing conviction from the time of Galileo,[3] when the experimental method may be said to have had its beginnings, is the exact antithesis of this. Stated in its most sweeping form, it holds that the universe is rationally intelligible, no matter how far from a complete comprehension of it we may now be, or indeed may ever come to be. It believes in the absolute uniformity of nature. It views the world as a mechanism, every part and every movement of which fits in some definite, invariable way into the other parts and the other movements; and it sets itself the inspiring task of studying every phenomenon in the confident hope that the connections between it and other phenomena can ultimately be found. It will have naught of caprice. Such is the spirit, the attitude, the work-

[3] See page 347, note 4.

ing hypothesis of all modern science; and this philosophy is in no sense materialistic, because good, and mind, and soul, and moral values,—these things are all here just as truly as are any physical objects; they must simply be inside and not outside of this matchless mechanism.

3. THE METHOD OF SCIENCE

Second, as to the method of science. It is a method practically unknown to the ancient world; for that world was essentially subjective in all its thinking, and built up its views of things largely by introspection. The scientific method, on the other hand, is a method which is completely objective. It is the method of the working hypothesis which is ready for the discard the very minute that it fails to work. It is the method which believes in a minute, careful, wholly dispassionate analysis of a situation; and any physicist or engineer who allows the least trace of prejudice or preconception to enter into his study of a given problem violates the most sacred duty of his profession. This present cataclysm,[4] which has set the world back a thousand years in so many ways, has shown us the pitiful spectacle of scientists who have forgotten completely the scientific method, and who have been controlled simply by prejudice and preconception. This fact is no reflection on the scientific method; it merely means that these men have not been able to carry over the methods they use in their science into all the departments of their thinking. The world has been controlled by prejudice and emotionalism so long that reversions still occur; but the fact that these reversions occur does not discredit the scientist, nor make him disbelieve in his method. Why? Simply because that method has worked; it is working to-day, and its promise of working

[4] This present cataclysm. The World War, 1914-1918.

to-morrow is larger than it has ever been before in the history of the world.

Do you realize that within the life of men now living, within a hundred years, or one hundred and thirty years at most, all the external conditions under which man lives his life on this earth have been more completely revolutionized than during all the ages of recorded history which preceded? My great-grandfather lived essentially the same kind of life, so far as external conditions were concerned, as did his Assyrian prototype six thousand years ago. He went as far as his own legs, or the legs of his horse, could carry him. He dug his ditch, he mowed his hay, with the power of his own two arms, or the power of his wife's two arms, with an occasional lift from his horse or his ox. He carried a dried potato in his pocket to keep off rheumatism, and he worshipped his God in almost the same superstitious way. It was not until the beginning of the nineteenth century that the great discovery of the ages began to be borne in upon the consciousness of mankind through the work of a few patient, indefatigable men who had caught the spirit which Galileo perhaps first notably embodied, and passed on to Newton,[5] to Franklin,[6] to Faraday,[7] to Maxwell,[8] and to the other great architects of the modern scientific world in which we live,—the discovery that man is not a pawn in a game played by higher powers, that his external as well as his internal destiny is in his own hands.

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[5] Sir Isaac Newton (1642-1727). An English mathematician who announced the laws of gravitation.

[6] Benjamin Franklin (1706-1790). An American philosopher, who, in 1752, proved that lightning is an electrical discharge.

[7] Michael Faraday (1791-1867). An English physicist and chemist.

[8] James Clerk-Maxwell (1831-1879). An English physicist. Professor of Experimental Physics in the University of Cambridge.

4. THE FAITH OF SCIENCE

You may prefer to have me call that not a discovery but a faith. Very well! It is the faith of the scientist, and it is a faith which he will tell you has been justified by works. Take just this one illustration. In the mystical, fatalistic ages, electricity was simply the agent of an inscrutable Providence: it was Elijah's fire [9] from Heaven sent down to consume the enemies of Jehovah, or it was Jove's thunderbolt [10] hurled by an angry god; and it was just as impious to study so direct a manifestation of God's power in the world as it would be for a child to study the strap with which he is being punished, or the mental attributes of the father who wields the strap. It was only one hundred and fifty years ago that Franklin sent up his famous kite, and showed that thunderbolts are identical with the sparks which he could draw on a winter's night from his cat's back. Then, thirty years afterward Volta [11] found that he could manufacture them artificially by dipping dissimilar metals into an acid. And, thirty years farther along, Oersted [12] found that, when tamed and running noiselessly along a wire, they will deflect a magnet; and with that discovery the electric battery was born, and the erstwhile blustering thunderbolts were set the inglorious task of ringing house bells, primarily for the convenience of womankind. Ten years later Faraday found that all he had to do to obtain a current

[9] Elijah's fire. "And Elijah answered and said to the captain of fifty, 'If I be a man of God, then let fire come down from Heaven and consume thee and thy fifty.' And there came down fire from heaven and consumed him and his fifty." II Kings, 1:10.

[10] Jove's thunderbolt. Jove, the chief Roman god, wielded the thunderbolt as his weapon.

[11] Count Alessandro Volta (1745-1827). An Italian physicist, noted for his investigations of electricity. He invented the electroscope.

[12] Hans Christian Oersted (1777-1851). A Danish physicist, the discoverer of electro-magnetism.

was to move a wire across the pole of a magnet, and in that discovery the dynamo was born, and our modern electrical age, with its electric transmission of power, its electric lighting, its electric telephoning, its electric toasting, its electric foot warming, and its electric milking. All that is an immediate and inevitable consequence of that discovery,—a discovery which grew out of the faith of a few physicists that the most mysterious, the most capricious, and the most terrible of natural phenomena is capable of a rational explanation, and ultimately amenable to human control.

5. THE VALUE OF SCIENCE

At the end of the nineteenth century there were many physicists and engineers who thought that all the great discoveries had been made. It was a common statement that this was so. I heard it made publicly in 1894; and yet within a year of that time I happened to be present in Berlin at the meeting of the Physical Society at which Roentgen [13] showed his first photographs, and since that time we have had a whole new world, the very existence of which was undreamed of before, opened up to our astonished eyes. We have found a world of electrons which underlies the world of atoms and molecules with which we had been familiar, and the discoveries in that world have poured in so rapidly within the last twenty years that there are no two decades in human history that compare at all with them in rapidity of advance. And these discoveries have been made for the most part by groups of men interested merely in finding out how nature works. They have been made almost exclusively by college profes-

[13] Wilhelm Konrad Roentgen (1845-). A German physicist, the discoverer of X-rays.

sors; and for ten years they remained the exclusive property of these professors. What has happened in the last ten years? The industrial world has fallen over itself in its endeavor to get hold of these advances; and by their aid it has increased ten-fold the power of the telephone; it has obtained four or five times as much light as we got a few years ago out of a given amount of electrical power; it has developed new kinds of transformers the existence of which was never dreamed of before. All these things are coming *now;* and how many more are going to come, no man can tell.

And yet we must not focus our attention too intently upon the utility of a discovery. Did you ever hear the story of what happened when Faraday was making before the Royal Society, in 1831, the experiment to which your Chairman referred? He performed his experiment, and then explained it. It was simple; it did not look particularly interesting. And a woman in the audience said, "But, Professor Faraday, of what *use* is it?" His reply was, "Madam, will you tell me of what use is a newborn babe?"—and what a reply it was! Infinite possibilities,—possibilities which may indeed not be realized, but at any rate something *altogether new.* Faraday did not care about the *immediate* use; for he was one of the great souls who had caught the spirit of Galileo. He knew that human progress depends primarily upon the *growth of the human mind,* the ability of man to get hold of Nature. The utilities might come. They always do come, but they generally crop out as by-products; and the man who has got his mind fixed merely on utilities is simply the man who kills the hen to get the golden egg. I have just as much respect for utilities as anybody has. I believe that nothing is worth while except as it contributes in the end to human progress;

but the difficulty is that you cannot tell, nor can I, nor can anybody else, what is going to contribute to human progress. The thing that is important is that the human mind should grow. That is the *sine qua non* [14] of progress.

At the Capitol in Harrisburg [15] is a picture by Sir Edwin Abbey,[16] which is entitled, "Wisdom, or the Spirit of Science." It consists of a veiled figure with the forked lightnings in one hand, and in the other, the owl and the serpent, the symbols of mystery; and beneath is the inscription:

> I am what is, what hath been, and what shall be.
> My veil has been disclosed by none.
> What I have brought forth is this: The sun is born.

It is to lighten man's understanding, to illuminate his path through life, and not merely to make it easy, that science exists. Hence, if you ask me what are the utilities of the particular category of discoveries which I am going to run over here very rapidly, I may be able to tell you of a good many of them; but I shall not try to catalogue them all, because that is not where our immediate interest lies. "Where there is no *vision* the people perish." [17]

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The Spirit of Scientific Research

1 What is the spirit of scientific research?
2 What is meant by the "philosophy," the "method," and the "faith" of science?

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[14] *Sine qua non.* Necessity.

[15] Harrisburg. The capital of Pennsylvania.

[16] Sir Edwin Abbey (1852-1911). An American painter, noted especially for his paintings of "The Holy Grail," in the Boston Public Library.

[17] Where there is no vision. A quotation from Proverbs, 29:18.

2 The Philosophy of Science

3 How does the philosophy of modern science differ from the philosophy of ancient times?
4 What are some of the beliefs of modern physicists?

3 The Method of Science

5 Explain the method of modern science.
6 What are some of the events that made the last 130 years notable?

4 The Faith of Science

7 How does Professor Millikan explain the faith of science by referring to electricity?
8 What does Professor Millikan mean when he speaks of "The Faith of Science"?
9 What has been accomplished because of the faith of scientists?

5 The Value of Science

10 Are great discoveries yet to be made?
11 To what do we owe most of our recent great discoveries?
12 How important are teachers of science?
13 Should scientists seek to increase knowledge, or seek to find that which will be useful?
14 Upon what does human progress depend?
15 Explain the quotation that accompanies the picture called "Wisdom, or the Spirit of Science."
16 What is the true purpose of science?

BOOKS FOR FURTHER READING

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THE SCIENTIFIC REVOLUTION

By

JAMES HARVEY ROBINSON

Reprinted from THE MIND IN THE MAKING, *by James Harvey Robinson, Harper and Brothers, Publishers.*

"Modern scientific knowledge and theory have not remained matter merely for academic discourse and learned books, but have provoked the invention of innumerable practical devices which surround us on every hand."

JAMES HARVEY ROBINSON.

JAMES HARVEY ROBINSON
(1863-)

The Scientific Revolution is an extract from a thoughtful book that attracted great attention, *The Mind in the Making: The Relation of Intelligence to Social Reform,* a work of most stimulating power.

The author, James Harvey Robinson, is a close student of history, interested in the development of characteristics and tendencies rather than in dramatic events. He leads his readers to see the meanings that underlie the outer facts of history. Thus he is an interpreter of events rather than a mere narrator. Such work has interest and vitality because it contributes value.

Professor Robinson taught history in the University of Pennsylvania, Columbia University, and elsewhere. In 1919 he organized the New School for Social Research in New York. For some years he was Editor of the *Annals of the American Academy of Political and Social Science,* and later Editor of *The American Historical Review.*

Among his books are *The German Bundesrath* (1891); *Petrarch, the First Modern Scholar and Man of Letters* (with Henry W. Rolfe) (1899); *Introduction to the History of Western Europe* (1903); *Readings in European History* (1904-5); *The Development of Modern Europe* (with Charles A. Beard) (1907); *Readings in Modern European History* (with Charles A. Beard) (1908-9); *The New History* (1911); *Mediaeval and Modern Times* (1915); *The Mind in the Making* (1921); *The Humanizing of Knowledge* (1923); *The Ordeal of Civilization* (1926).

THE SCIENTIFIC REVOLUTION

By James Harvey Robinson

I. THE BEGINNING OF SCIENTIFIC THOUGHT

AT THE opening of the seventeenth century a man of letters, of sufficient genius to be suspected by some of having written the plays of Shakespeare, directed his distinguished literary ability to the promotion and exaltation of natural science. Lord Bacon was the chief herald of that habit of scientific and critical thought which has played so novel and all-important a part in the making of the modern mind. When but twenty-two years old he was already sketching out a work which he planned to call *Temporis Partus Maximus* (*The Greatest Thing Ever*). He felt that he had discovered why the human mind, enmeshed in mediæval metaphysics and indifferent to natural phenomena, had hitherto been a stunted and ineffective thing, and how it might be so nurtured and guided as to gain undreamed of strength and vigor.

And never has there been a man better equipped with literary gifts to preach a new gospel than Francis Bacon. He spent years in devising eloquent and ingenious ways of delivering learning from the "discredits and disgraces" of the past, and in exhorting man to explore the realms of nature for his delight and profit. He never wearied of trumpeting forth the glories of the new knowledge which would come with the study of common things and the profitable uses to

which it might be put in relieving man's estate. He impeached the mediæval schoolmen for spinning out endless cobwebs of learning, remarkable for their fineness, but of no substance or spirit. He urged the learned to come out of their cells, study the creations of God, and build upon what they discovered a new and true philosophy.

Even in his own day students of natural phenomena had begun to carry out Bacon's general program with striking effects. While he was urging men to cease "tumbling up and down in their own reason and conceits" and to spell out, and so by degrees to learn to read, the volume of God's works, Galileo had already begun the reading and had found out that the Aristotelian physics [1] ran counter to the facts; that a body once in motion will continue to move forever in a straight line unless it be stopped or deflected. Studying the sky through his newly invented telescope, he beheld the sun spots and noted the sun's revolution on its axis, the phases of Venus,[2] and the satellites of Jupiter.[3] These discoveries seemed to confirm the ideas advanced long before by Copernicus [4]—the earth was *not* the center of the universe and the heavens were *not* perfect and unchanging. He dared to discuss these matters in the language of the people and was, as everyone knows, condemned by the Inquisition.[5]

This preoccupation with natural phenomena and this re-

[1] Aristotelian physics. The old conception of physics, founded upon the philosophy of Aristotle (384 B.C.-322 B.C.).

[2] Phases of Venus. The varying appearances of the planet Venus, corresponding to the varying appearances of the moon, such as new moon, half moon, full moon.

[3] Satellites of Jupiter. The mine moons of the planet Jupiter.

[4] Copernicus. (1473-1543). A great German astronomer, the founder of modern astronomy.

[5] Inquisition. A church court organized in 1231 for the trial of heretics.

fusal to accept the old, established theories until they had been verified by an investigation of common fact was a very novel thing. It introduced a fresh and momentous element into our intellectual heritage. We have recalled the mysticism, supernaturalism, and intolerance of the Middle Ages, their reliance on old books, and their indifference to everyday fact except as a sort of allegory for the edification of the Christian pilgrim. In the mediæval universities the professors, or "schoolmen," devoted themselves to the elaborate formulation of Christian doctrine and the interpretation of Aristotle's works. It was a period of Greek metaphysics,[6] adapted to prevailing religious presuppositions. Into this fettered world Bacon, Galileo, Descartes,[7] and others brought a new aspiration to promote investigation and honest, critical thinking about everyday things.

These founders of modern natural science realized that they would have to begin afresh. This was a bold resolve, but not so bold as must be that of the student of mankind today if he expects to free himself from the trammels of the past. Bacon pointed out that the old days were not those of mature knowledge, but of youthful human ignorance. "*These* times are the ancient times, when the world is ancient, and not those we count ancient, *ordine retrogrado*,[8] by a computation backward from ourselves." In his *New Atlantis*[9] he pictures an ideal State which concentrated its resources on systematic scientific research, with a view to applying new discoveries to the betterment of man's lot.

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[6] Metaphysics. Principles of philosophy.

[7] René Descartes (1596-1650). A French philosopher.

[8] *Ordine retrogrado.* In reverse order.

[9] *New Atlantis.* An imaginary ocean island, the setting of a romance by Francis Bacon.

2. DEVELOPMENT OF THE QUESTIONING SPIRIT

Descartes, who was a young man when Bacon was an old one, insisted on the necessity, if we proposed to seek the truth, of questioning *everything* at least once in our lives. To all these leaders in the development of modern science doubt, not faith, was the beginning of wisdom. They doubted—and with good reason—what the Greeks were supposed to have discovered; they doubted all the old books and all the university professors' lecture notes. They did not venture to doubt the Bible, but they eluded it in various ways. They set to work to find out exactly what happened under certain circumstances. They experimented individually and reported their discoveries to the scientific academies which began to come into existence.

As one follows the deliberations of these bodies it is pathetic to observe how little the learning of previous centuries, in spite of its imposing claims, had to contribute to a fruitful knowledge of common things. It required a century of hard work to establish the most elementary facts which would now be found in a child's book. How water and air act, how to measure time and temperature and atmospheric pressure, had to be discovered. The microscope revealed the complexity of organic tissues, the existence of minute creatures, vaguely called infusoria, and the strange inhabitants of the blood, the red and white corpuscles. The telescope put an end to the flattering assumption that the cosmos circled around man and the little ball he lives on.

Without a certain un-Greek, practical inventive tendency which, for reasons not easily to be discovered, first began to manifest itself in the thirteenth century, this progress would not have been possible. The new thinkers descended from

the magisterial chair and patiently fussed with lenses, tubes, pulleys, and wheels, thus weaning themselves from the adoration of man's mind and understanding. They had to devise the machinery of investigation as investigation itself progressed.

Moreover, they did not confine themselves to the conventionally noble and elevated subjects of speculation. They addressed themselves to worms and ditch water in preference to metaphysical subtleties. They agreed with Bacon that the mean and even filthy things deserve study. All this was naturally scorned by the university professors, and the universities consequently played little or no part in the advance of natural science until the nineteenth century.

Nor were the moral leaders of mankind behind the intellectual in opposing the novel tendencies. The clergy did all they could to perpetuate the squalid belief in witchcraft, but found no place for experimental science in their scheme of learning, and judged it offensive to the Maker of all things. But their opposition could do no more than hamper the new scientific impulse, which was far too potent to be seriously checked.

So in one department of human thought—the investigation of natural processes—majestic progress has been made since the opening of the seventeenth century, with every promise of continued and startling advance. The new methods employed by students of natural science have resulted in the accumulation of a stupendous mass of information in regard to the material structure and operation of things, and the gradual way in which the earth and all its inhabitants have come into being. The nature and workings of atoms and molecules are being cleared up, and their relation to heat, light, and electricity established. The slow processes which have brought about the mountains and valleys, the seas and plains,

have been exposed. The structure of the elementary cell can be studied under powerful lenses; its divisions, conjunctions, differentiation, and multiplication into the incredibly intricate substance of plants and animals can be traced.

In short, man is now in a position, for the first time in his history, to have some really clear and accurate notion of the world in which he dwells and of the living creatures which surround him and with which he must come to terms. It would seem obvious that this fresh knowledge should enable him to direct his affairs more intelligently than his ancestors were able to do in their ignorance. He should be in a position to accommodate himself more and more successfully to the exigencies of an existence which he can understand more fully than any preceding generation, and he should aspire to deal more and more sagaciously with himself and his fellow-men.

3. HOW SCIENTIFIC KNOWLEDGE HAS REVOLUTIONIZED THE CONDITIONS OF LIFE

But while our information in regard to man and the world is incalculably greater than that available a hundred, even fifty years ago, we must frankly admit that the knowledge is still so novel, so imperfectly assimilated, so inadequately co-ordinated, and so feebly and ineffectively presented to the great mass of men, that its *direct* effects upon human impulses and reasoning and outlook are as yet inconsiderable and disappointing. We *might* think in terms of molecules and atoms, but we rarely do. Few have any more knowledge of their own bodily operations than had their grandparents. The farmer's confidence in the phases of the moon gives way but slowly before recent discoveries in regard to the bacteria of the soil. Few who use the telephone, ride on electric cars, and

carry a camera have even the mildest curiosity in regard to how these things work. It is only *indirectly,* through *invention,* that scientific knowledge touches our lives on every hand, modifying our environment, altering our daily habits, dislocating the anciently established order, and imposing the burden of constant adaptation on even the most ignorant and lethargic.

Unlike a great part of man's earlier thought, modern scientific knowledge and theory have not remained matter merely for academic discourse and learned books, but have provoked the invention of innumerable practical devices which surround us on every hand, and from which we can now scarce escape by land or sea. Thus while scientific knowledge has not greatly affected the thoughts of most of us, its influence in the promotion of modern invention has served to place us in a new setting or environment, the novel features of which it would be no small task to explain to one's great-great-grandfather, should he unexpectedly apply for up-to-date information. So even if modern scientific *knowledge* is as yet so imperfect and ill understood as to make it impossible for us to apply much of it directly and personally in our daily conduct, we nevertheless cannot neglect the urgent effects of scientific *inventions,* for they are constantly posing new problems of adjustment to us, and sometimes disposing of old ones.

Let us recall a few striking examples of the astonishing way in which what seemed in the beginning to be rather trivial inventions and devices have, with the improvements of modern science, profoundly altered the conditions of life.

Some centuries before the time of Bacon and Galileo four discoveries were made which, supplemented and elaborated by later insight and ingenuity, may be said to underlie our

modern civilization. A writer of the time of Henry II[10] of England reports that sailors when caught in fog or darkness were wont to touch a needle to a bit of magnetic iron. The needle would then, it had been found, whirl around in a circle and come to rest pointing north. On this tiny index the vast extension of modern commerce and imperialism rests.

That lentil-shaped bits of glass would magnify objects was known before the end of the thirteenth century, and from that little fact have come microscopes, telescopes, spectroscopes, and cameras; and from these in turn has come a great part of our present knowledge of natural processes in men, animals, and plants and our comprehension of the cosmos at large.

Gunpowder began to be used a few decades after the lens was discovered; it and its terrible descendants have changed the whole problem of human warfare and of the public defense.

The printing press, originally a homely scheme for saving the labor of the copyist, has not only made modern democracy and nationality possible, but has helped by the extension of education to undermine the ancient foundations upon which human industry has rested from the beginnings of civilization.

In the middle of the eighteenth century the steam engine began to supplant the muscular power of men and animals, which had theretofore been only feebly supplemented by windmills and water wheels. And now we use steam and gas engines and water power to generate potent electric currents which do their work far from the source of supply. Mechanical ingenuity has utilized all this undreamed-of energy in innumerable novel ways for producing old and new com-

[10] Henry II of England (1133-1189). King of England, 1154-1189.

modities in tremendous quantities and distributing them with incredible rapidity throughout the earth.

Vast factories have sprung up, with their laborious multitudes engaged on minute contributions to the finished article; overgrown cities sprawl over the neighboring green fields and pastures; long freight trains of steel cars thunder across continents; monstrous masses of wealth pile up, are reinvested, and applied to making the whole system more and more inconceivably intricate and interdependent; and incidentally there is hurry and worry and discontent and hazard beyond belief for a creature who has to grasp it all and control it all with a mind reared on that of an animal, a child, and a savage.

As if these changes were not astounding enough, now has come the chemist who devotes himself to making not new *commodities* (or old ones in new ways), but new *substances*. He juggles with the atoms of carbon, hydrogen, oxygen, nitrogen, chlorine, and the rest, and far outruns the workings of nature. Up to date he has been able to produce artfully over two hundred thousand compounds, for some of which mankind formerly depended on the alchemy of animals and plants. He can make foodstuffs out of sewage; he can entrap the nitrogen in the air and use it to raise wheat to feed, or high explosives to slaughter, his fellows. He no longer relies on plants and animals for dyes and perfumes. In short, a chemical discovery may at any moment devastate an immemorial industry and leave both capital and labor in the lurch. The day may not be far distant when, should the chemist learn to control the incredible interatomic energy, the steam engine will seem as complete an anachronism as the treadmill.

The uttermost parts of the earth have been visited by Europeans, and commerce has brought all races of the globe into close touch. We have now to reckon with every nation under

heaven, as was shown in the World War. At the same time steam and electrical communication have been so perfected that space has been practically annihilated as regards speech, and in matters of transportation reduced to perhaps a fifth. So all the peoples of the earth form economically a loose and, as yet, scarcely acknowledged federation of man, in which the fate of any member may affect the affairs of all the others, no matter how remote they may be geographically.

All these unprecedented conditions have conspired to give business for business' sake a fascination and overwhelming importance it has never had before. We no longer make things for the sake of making them, but for money. The chair is not made to sit on, but for profit; the soap is no longer prepared for purposes of cleanliness, but to be sold for profit. Practically nothing catches our eye in the way of writing that was written for its own sake and not for money. Our magazines and newspapers are our modern commercial travelers proclaiming the gospel of business competition. Formerly the laboring classes worked because they were slaves, or because they were defenseless and could not escape from thraldom—or, mayhap, because they were natural artisans; but now they are coming into a position where they can combine and bargain and enter into business competition with their employers. Like their employers, they are learning to give as little as possible for as much as possible. This is good business; and the employer should realize that at last he has succeeded in teaching his employees to be strictly businesslike. When houses were built to live in, and wheat and cattle grown to eat, these essential industries took care of themselves. But now that profit is the motive for building houses and raising grain, if the promised returns are greater from manufacturing automobiles or embroidered lingerie, one is tempted to ask

if there are any longer compelling reasons for building houses or raising food?

4. THE DEVELOPMENT OF DEMOCRACY AND NATIONALITY

Along with the new inventions and discoveries and our inordinately pervasive commerce have come two other novel elements in our environment—what we vaguely call "democracy" and "nationality." These also are to be traced to applied science and mechanical contrivances.

The printing press has made popular education possible, and it is our aspiration to have every boy and girl learn to read and write—an ideal that the Western World has gone far to realize in the last hundred years. General education, introduced first among men and then extended to women, has made plausible the contention that all adults should have a vote, and thereby exercise some ostensible influence in the choice of public officials and in the direction of the policy of the government.

Until recently the mass of the people have not been invited to turn their attention to public affairs, which have been left in the control of the richer classes and their representatives and agents, the statesmen or politicians. Doubtless our crowded cities have contributed to a growing sense of the importance of the common man, for all must now share the street car, the public park, the water supply, and contagious diseases.

But there is a still more fundamental discovery underlying our democratic tendencies. This is the easily demonstrated scientific truth that nearly all men and women, whatever their social and economic status, may have much greater possibilities of activity and thought and emotion than they exhibit in the particular conditions in which they happen to be placed; that in all ranks may be found evidence of unrealized

capacity; that we are living on a far lower scale of intelligent conduct and rational enjoyment than is necessary.

Our present notions of nationality are of very recent origin, going back scarcely a hundred years. Formerly nations were made up of the subjects of this or that gracious majesty and were regarded by their God-given rulers as beasts of burden or slaves or, in more amiable moods, as children. The same forces that have given rise to modern democracy have made it possible for vast groups of people, such as make up France or the United States, to be held together more intimately than ever before by the news which reaches them daily of the enterprises of their government and the deeds of their conspicuous fellow-countrymen.

In this way the inhabitants of an extensive territory embracing hundreds of thousands of square miles are brought as close together as the people of Athens in former days. Man is surely a gregarious animal who dislikes solitude. He is, moreover, given to the most exaggerated estimate of his tribe; and on these ancient foundations modern nationality has been built up by means of the printing press, the telegraph, and cheap postage. *So it has fallen out that just when the world was becoming effectively cosmopolitan in its economic interdependence, its scientific research, and its exchange of books and art, the ancient tribal insolence has been developed on a stupendous scale.*

The manner in which man has revolutionized his environment, habits of conduct, and purposes of life by inventions is perhaps the most astonishing thing in human history. It is an obscure and hitherto rather neglected subject. But it is clear enough, from the little that has been said here, that since the Middle Ages, and especially in the past hundred years, science has so hastened the process of change that it

becomes increasingly difficult for man's common run of thinking to keep pace with the radical alterations in his actual practices and conditions of living.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 The Beginning of Scientific Thought

1 What new knowledge came with the study of common things?
2 How did the new knowledge help common people?
3 What good results come from the investigation of all natural phenomena?
4 To what extent should people free themselves from the trammels of the past?
5 What did Bacon mean when he spoke of "mature knowledge" and of "youthful human ignorance"?
6 Why are "these times" the "ancient times"?
7 To what extent has the modern world approached Bacon's ideal state?

2 Development of the Questioning Spirit

8 How can doubt be the beginning of wisdom?
9 What laid the foundations of modern learning?
10 What subjects are worthy of investigation?
11 What advantages do we have to-day that would have seemed wonderful to the people of the past?

3 How Scientific Knowledge Has Revolutionized the Conditions of Life

12 What may we expect for the people of the future?
13 How does Scientific knowledge touch the lives of common people?
14 Write an original short story in which you present a noted person of the past confronted with some of our modern inventions.
15 If you read Mark Twain's *A Connecticut Yankee at King Arthur's Court,* tell the story, relating it to the thought of *The Scientific Revolution.*
16 Explain the importance of certain great inventions that underlie modern civilization.

17 Under what conditions should we be living today if we lacked the benefits of great inventions?
18 What disadvantages accompany the benefits of modern science and invention?
19 What new wonders is chemistry performing?
20 In what ways has the world become more nearly unified?
21 In what ways are we approaching what Tennyson called "The parliament of man, the federation of the world"?
22 What causes developed the present commercial spirit?

4 The Development of Democracy and of Nationality

23 What causes developed "democracy" and "nationality"?
24 What changes have taken place in the condition of humble people?
25 Explain your reasons for believing that the world to-day is, or is not, at its best.
26 What influences developed modern great nations?
27 Prove that the existence of nationalism tends to aid, or to hinder, the best development of mankind.
28 Summarize the principal thoughts of the article.
29 In what respects does the article lead you to believe that the world is improving?
30 What does the article lead you to hope for the future?
31 Name and explain various new discoveries or inventions made in your own lifetime. Tell what advantages, or disadvantages, they may bring.
32 Explain what science contributes to your own daily happiness.

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DESIGN IN CREATION

By

SIR OLIVER LODGE

Reprinted from ETHER AND REALITY, *by Sir Oliver Lodge, by permission of the Publishers, Hodder and Stoughton, Ltd., London, England, and Doubleday, Doran and Company, Inc., New York.*

"Everything points to the rational scheme or plan, of which we know neither the beginning nor the end, but towards the fulfilment of which we can help."

SIR OLIVER LODGE.

SIR OLIVER LODGE

(1851-)

The coherer used in wireless telegraphy is the invention of Sir Oliver Lodge, a great English physicist. In addition to his work in developing wireless telegraphy Sir Oliver Lodge also carried on various experiments with electro-magnetic waves, studied lightning and its effects, and made special studies of electrolysis and the voltaic cell.

In his early life Sir Oliver Lodge turned from a business career in order to study science. He became Professor of Physics in the University College, Liverpool (1881-1900), and then Principal of the University of Birmingham. In 1920 he lectured in the United States.

In 1902 he was made Fellow of the Royal Society, and a Knight. In 1919 he was awarded the Albert Medal of the Royal Society of Arts for pioneer work in the development of wireless telegraphy.

Among Sir Oliver Lodge's books are the following: *Elementary Mechanics* (1877); *Modern Views of Electricity* (1889); *Pioneers of Science* (1893); *Electrons* (1907); *Science and Immortality* (1908); *The Ether of Space* (1909); *The Survival of Man* (1909); *Reason and Belief* (1911); *The Making of Man* (1924); *Ether and Reality* (1925); *Relativity* (1925); *Talks About Wireless* (1925).

DESIGN IN CREATION

By Sir Oliver Lodge

THE ages of the earth's past seem to have been a sort of preparation for the life and mind which now is, and for the mind which is still to come. It has been a slow and laborious process; and the outcome of it, so far, we see. Has the outcome been worth all the labor and time spent in preparation? Faith is needed to suppose that. Mankind with its trivialities seems hardly worthy. Yet by faith we feel bound to suppose that there is some far-seeing design, some lofty meaning in it all, and that the ultimate outcome will be worth while.

Meanwhile, here we are, conscious creatures endowed with the faculty of understanding; with the power of work, and of mutual help: we have become agents in the universe endowed with consciousness. We are beginning to understand something of the processes at work. We are beginning even to have some power, not only of understanding but of helping, of doing things which would not otherwise be done. We have the power to produce works of art, to rearrange matter into beautiful forms, to exhibit emotions, to glorify existence by human achievements, to express feelings and hopes and aspirations, to add to the real wealth or value of existence. And so, even while still within the range of the material universe, we may hope that mankind will become worthy of the magnificent scene in which its lot is cast. We ourselves, though we are but a stage in the majestic pageant,

can yet understand that here on earth is scope for free response to a Divine Will, and can wonder at the patient effort.

Depend upon it, nothing is easy, nothing petty, nor is anything haphazard; things are not left to chance. Everything is amenable to law and order, everything points to the rational scheme or plan, of which we know neither the beginning nor the end, but towards the fulfilment of which we can help. In face of all that, shall we allow ourselves to squabble about trivialities? Shall we crawl about on the surface of the planet and sting each other here in the dust and die? Or shall we realize that we are the heir of all the ages, that the destiny of mankind is being partly entrusted to us, and that humanity has a future, a potential future, beyond our wildest dreams.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 Show how past ages prepared for the world of today.
2 How are we preparing for the world of the future?
3 Toward what does Sir Oliver Lodge believe the world is moving?
4 In what sense are we "agents" in the universe?
5 What does Sir Oliver Lodge mean by "real wealth"?
6 What do you think Sir Oliver Lodge would say if he were to explain his words, "The value of existence"?
7 Why does Sir Oliver Lodge call life a "majestic pageant"?
8 What does Sir Oliver Lodge mean by a "rational scheme or plan, seen in all things"?
9 How should knowledge of science affect one's attitude toward life?
10 What does Sir Oliver Lodge hope for the future?

BOOKS FOR FURTHER READING

Pioneers of Science, Sir Oliver Lodge, *Macmillan,* 1904.
Science and Immortality, Sir Oliver Lodge, *Moffet,* 1908.
The Making of Man, Sir Oliver Lodge, *Doran,* 1924.

Evolution and Creation, Sir Oliver Lodge, *Hodder and Stoughton,* London, 1926.
The Ascent of Man, Henry Drummond, *J. Pott,* 1904.
The Outline of History, H. G. Wells, *Macmillan,* 1926.
Creative Evolution, H. L. Bergson, *Holt,* 1911.
What Is Man? J. Arthur Thompson, *Putnam,* 1924.
Social Heredity and Social Evolution, Herbert William Conn, *Abingdon Press,* 1914.
Heir of All the Ages, N. K. McKechnie, *Bobbs-Merrill,* 1926.

PIVOTAL FIGURES OF SCIENCE

By

ARTHUR ELMORE BOSTWICK

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"The lives of the great scientific men show that they all have something in common—a passion for truth, a lifelong effort to get at new facts and to explain the old ones, a 'divine curiosity,' pursued for its own sake and not for that of any personal advantage."

ARTHUR E. BOSTWICK.

ARTHUR ELMORE BOSTWICK
(1860-)

As editor of the Science Department of *The Literary Digest* since 1891, Arthur E. Bostwick has done important work in interesting people in the progress of modern science. As associate editor, and as authority in physics for the *Standard Dictionary,* and also as writer of the yearly review of progress in physics for *Appleton's Cyclopedia,* he has aided materially in recording the development of science. All this was foreshadowed by his early interest in science, that led to his becoming the first holder of the Silliman Fellowship in Physics at Yale, and later to his teaching science for three years.

Dr. Bostwick's interest in writing led him to become a member of the staff of *Appleton's Cyclopedia of American Biography,* and also associate editor of *The Forum.*

As Chief Librarian of the New York Free Circulating Library, and now as Head Librarian of the St. Louis Public Library, he has done valuable work in leading people to wisely directed, thoughtful reading. In 1925 he traveled in China, on the invitation of the Chinese Association for the Advancement of Education, to inspect the libraries of China and to suggest improvements.

Dr. Bostwick is the author of many books, among them being the following: *Young Folks Cyclopedia of Games and Sports* (with John D. Chamberlin, Jr.); *The American Public Library; The Different West; Earmarks of Literature; The Making of an American's Library; Classics of American Librarianship; Library Essays; A Librarian's Open Shelf.*

PIVOTAL FIGURES OF SCIENCE

By Arthur Elmore Bostwick

I. POPULAR APPRECIATION OF SCIENCE

FIFTY years ago pure science, in the popular mind of this country, was largely a theme for jests, as something having to do largely with odd experiments and jaw-breaking names. It rarely figured in the public press, and gatherings of scientific bodies were noticed therein chiefly in a spirit of banter. About once a year, Charles A. Dana, the able but eccentric editor of the New York *Sun,* contributed to that paper a mock-serious discussion of the publications of the United States Bureau of Entomology,[1] in which the long Latin names of genera and species were held up to ridicule. Otherwise the struggles and triumphs of science were not for his pages.

We have changed all this. Science has been discovered by the American public and the American press. American industry has found that it cannot get along without the help of science, and expensive laboratories now form part of the equipment of our great factories.

This gain in popular appreciation, to be sure, has to do with the applications of science, rather than with science itself; but interesting as a machine may be, the principles on which it works are even more fascinating to the thinking mind.

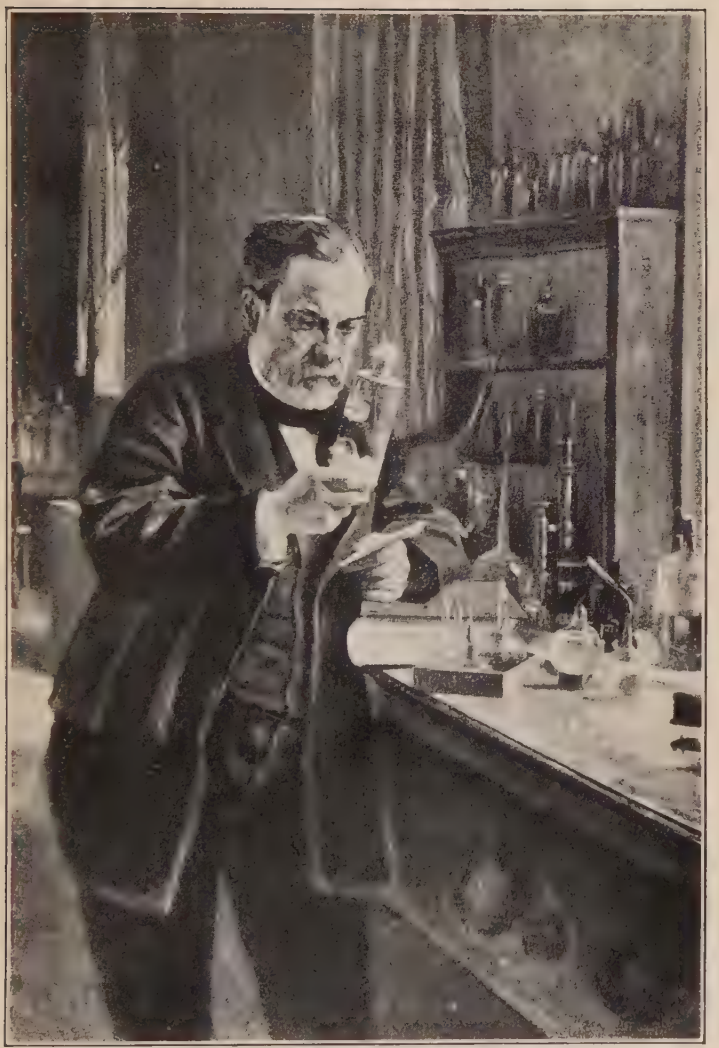
[1] Bureau of Entomology. A United States Government department devoted to the study of insect life.

2. THE SCIENTIST AND THE INVENTOR

Science, as we understand the term today, is not old. It is concerned principally with the systematic discovery and organization of facts. It does these things:

1. Brings to light new facts
2. Groups all facts by similarity
3. Formulates statements, called laws, explaining these groupings
4. Applies these laws in the discovery of still other facts.

Facts and laws thus treated are often, though not always, utilizable in increasing the comforts, opportunities or abilities of mankind. Those who so use them are inventors. Inventions, with some notable exceptions, are the work of many persons, simultaneously or in succession. When the work finally achieves success, often through a happy accident, by the removal of a final obstacle, the last worker usually receives the entire credit, in popular estimation, and is hailed as the "inventor." These inventors are the men best known as scientific workers because their results are sensational and appeal to all. Their predecessors, the investigators in pure science, are less known, and the records of what they have done are locked up in technical papers and reports. The public knows little, and cares less, about them personally; and one searches in vain, in most cases, for readable popular books on their lives and work. This is not remarkable when we reflect that what are really the great events of their lives have taken place not in the realm of action but in that of the intellect. Details in the life of a soldier or a statesman interest the general reader because they are of a sort that he can readily understand, while in the case of a scientific investigator, their relations to his own daily life seem decidedly remote.



Ewing Galloway, N. Y. *From a painting by Edelfelt*

LOUIS PASTEUR
Chemist, Bacteriologist, Beneficent Friend of Man

The history of science is full of the tragedy of public neglect awarded to the worker in pure science while the inventor of some industrial device is widely acclaimed. Our own greatest scientist, Josiah Willard Gibbs,[2] lived the retired life of a university professor, little known, and unappreciated even by his colleagues. Pierre and Marie Curie[3] made their great discovery of radium in a little shed with the poorest kind of apparatus. Earlier still, the investigator in pure science was the object of suspicion and contumely. Galileo,[4] the first astronomical discoverer, was even imprisoned and forced to disown his own discoveries.

3. TYPES OF DISCOVERY

What are the things that these men discover? They are:

1. Previously unknown things
2. Previously unknown relations—causes, laws
3. New combinations of old or new or both.

The first two are discovery pure and simple. The third is of the nature of creation—the finding of something that never existed before.

When the Italian Galileo first saw the sunspots, when our own Asaph Hall[5] brought to light the moons of Mars, when

[2] Josiah Willard Gibbs (1839-1903). An American physicist, Professor of Mathematical Physics in Yale University.

[3] Pierre and Marie Curie. In 1898 Pierre Curie (1859-1906), a French physicist, and his wife, Marie Sklodowska Curie (1867-), of Polish birth, following the work of Henri Becquerel, discovered radium.

[4] Galileo (1564-1642). An Italian experimenter, Professor of Mathematics in Pisa and in Padua, maker of the first thermometer, and of one of the first telescopes, and discoverer of the moons of the planet Jupiter.

[5] Asaph Hall (1829-1907). An American astronomer, for many years connected with the Naval Observatory at Washington, D. C., and later Professor of Astronomy in Harvard University. In 1877 he discovered two moons of the planet Mars.

Heinrich Hertz[6] discovered electric waves in Germany and Pierre Curie and his wife extracted radium from pitchblende in France, they were doing precisely what Columbus did. These things had existed before, just as America had. They were now merely made known to man.

In a slightly different class were the laws of planetary motion, deduced by Kepler,[7] the discovery of universal gravitation by Newton,[8] of the connection between electricity and magnetism by Ampère,[9] of the electro-magnetic nature of sunspots by George Hale.[10] These scientists did not discover the planets, magnets and sunspots; they found out something about them, and what they discovered was in the nature of an explanation. It is this explanatory function—the attempt to answer the questions "how" and "why"—that makes science fascinating to most of us. The unthinking man regards matter, for instance, the stuff of which everything about us is made, as something unnecessary to explain. He has always known it, and it is perfectly familiar. But sooner or later he begins to realize that there must be something behind it. Why should it be sometimes soft and sometimes hard? In turn solid, liquid and gaseous? Sometimes alive and sometimes dead? Why should the matter in a man's brain think, while that in a lump of coal does not? It is in answering such queries that science comes into being.

[6] Heinrich Hertz (1857-1894). A German physicist, a life-long student of electricity, whose work led ultimately to the development of wireless telegraphy.

[7] Johann Kepler (1571-1630). A German astronomer whose study of the movements of the planets led the way to modern astronomy.

[8] Sir Isaac Newton (1642-1727). An English mathematician, who announced the laws of gravitation.

[9] André Marie Ampère (1775-1836). A French physicist who made important studies in electro-dynamics.

[10] George Hale (1868-). An American astronomer, inventor of the spectroheliograph, an instrument used in observing the sun.

In the third class are such discoveries as that sound may be reproduced by purely mechanical means. This has been developed into an invention, the phonograph; but at first it was merely a scientific discovery, a combination that had never existed before—it was a creation, a something in place of nothing.

4. VALUE OF SCIENTIFIC KNOWLEDGE

Now of what use is scientific knowledge, old or new? What is, or can be, done with it?

1. It may simply be accumulated
2. It may be used to acquire new knowledge
3. It may be imparted to others
4. It may be applied.

In old times a "learned" man was one in possession of a vast accumulation of knowledge, often totally unused. Nowadays a scientific man is expected to add to the store of knowledge either by observation and experiment or by combination, generally with the aid of that powerful engine, modern mathematics. In this country he is also generally a teacher.

The fourth use, application, which is that best known to most of us, has produced the automobile, the telephone, the electric light, the aeroplane, the moving picture, radio—all the "modern improvements." It is looked upon askance by scientific men, and often relegated by them to outsiders. Those who have attained fame in it, as already noted, are the great inventors, Bell,[11] Edison,[12] Wright.[13] We are not considering them here.

[11] Alexander Graham Bell (1847-1922). An American physicist of Scotch birth; in 1876 the inventor of the telephone.

[12] Thomas Alva Edison (1847-). An American inventor, especially noted as the inventor of the incandescent electric lamp.

[13] Wilbur Wright (1867-1912), with his brother, Orville Wright (1871-), in 1903 invented the airplane.

The lives of the great scientific men show that they all have something in common—a passion for truth, a lifelong effort to get at new facts and to explain the old ones, a "divine curiosity," pursued for its own sake and not for that of any personal advantage. Such a frame of mind must be inborn; education cannot supply it. The scientist, like the poet, must be "born," not made. The English physicist, Clerk-Maxwell,[14] as a boy, used to ask, whenever he met with an unfamiliar device, "What is the go of it?" And if he received too vague an answer, he persisted, "Well, what is the *particular go?*" This passion to get at the "go" of things is characteristic of the scientific turn of mind.

But though a passion for truth cannot be created, it is often hidden and must be brought out and developed. Again, the search for new truth in these modern days requires a knowledge of what has already been found out and ability to use many complex tools and methods. This presupposes training.

5. DEVELOPMENT OF SCIENTIFIC THOUGHT

Science was originally, and thus still continues largely to be, a product of pure curiosity—the itching to know what things are and why they are. At first the "why" seems to have predominated. The personal act of some supernatural being was the basis of all early explanations; then came the crude mechanical systems, like those of the Greek philosophers. Epicurus,[15] for instance, believed matter to be made up of separate particles, just as we do, but explained cohesion by supposing these to be fitted with hooks that held the particles together. The necessity of inquiry by experimentation was entirely unrecognized in

[14] James Clerk-Maxwell (1831-1879). An English physicist, Professor of Experimental Physics in the University of Cambridge.

[15] Epicurus (342-270 B.C.). A Greek philosopher who deeply influenced all succeeding ages.

this stage, for the treatment of which the reader may be more properly referred to the various histories of philosophy, such as the good and popular *Story of Philosophy* by Will Durant.[16] They do not strictly belong in this list. Yet at this time physical science or "natural philosophy"—still occasionally so-called—was not generally distinguished from the metaphysical side. The most modern of them all was the Greek philosopher Aristotle,[17] the tutor of Alexander the Great, who continued to dominate the world of science far into the Middle Ages to such a degree that scholars who gazed through the earliest telescopes would not believe in the reality of what they saw since Aristotle had said nothing about it. Yet even he professed to base his work on what he saw about him and he may perhaps be ranked as the first observational scientist.

Experimental science was born in 1214 with Roger Bacon,[18] an English monk. His namesake Francis,[19] three hundred years later, did valuable work in developing method. The different branches of science now began to be discriminated—astronomy, physics, chemistry, biology—and the search for facts proceeded more systematically. The magnet was studied in England by Gilbert,[20] chemistry was built on the ruins of the old alchemy by Dalton[21] and Priestley,[22] Fresnel[23] in

[16] Will Durant (1885-). An American student of philosophy.

[17] Aristotle (384-322 B.C.). The greatest of Greek philosophers.

[18] Roger Bacon (1214-1294). A brilliant experimenter, student and author, whose work foreshadowed modern science.

[19] Francis Bacon (1561-1626). A great English philosopher who emphasized the value of observation and experiment.

[20] William Gilbert (1540-1603). An English philosopher, author of an early work on magnetism.

[21] John Dalton (1766-1844). An English chemist, who advanced the atomic theory.

[22] Joseph Priestley (1733-1804). An English philosopher, the discoverer of oxygen.

[23] Augustin Fresnel (1788-1827). A French physicist whose investigations led to the wave theory of light.

France developed optics, Fraunhofer[24] in Germany laid the foundations of spectroscopy.[25]

In our own day, after men had about concluded that all the facts of the physical world lay spread before them, and that henceforth the sole task of science would be to correlate and explain them, extraordinary new facts began to be brought to light—the existence of electro-magnetic waves, discovered by Heinrich Hertz; that of the X-rays, by Roentgen;[26] the rays found in France by Henri Becquerel[27] leading to the discovery of radium by the Curies and the reconstruction of a large part of physical science. The study of such novelties as these and the establishment of their connections with our previous knowledge has occupied much of the attention of present-day scientists, whose attitude now is that we are on the threshold of new discoveries and have penetrated only a little way into the secrets of nature. Nothing can be more valuable, and nothing should be more fascinating, than to follow the lives of such men as these through the pages of a well-written narrative that links what they thought and did with what they were.

6. SHORT BIOGRAPHIES

It is astonishing how little information is available regarding the lives of all these important men. Some collections of short sketches of groups of them may be the best introduction to their

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[24] Joseph von Fraunhofer (1787-1826). A German student of optics, who improved telescopes, and made important studies of the lines of the spectrum.

[25] Spectroscopy. The branch of science that concerns the spectroscope, an instrument used in studying light. In the simplest form the light is passed through a prism.

[26] Wilhelm Roentgen (1845-1923). A German scientist, in 1895 the discoverer of X-rays.

[27] Henri Becquerel (1852-1908). A French physicist who discovered radiation from uranium.

careers. Three books are recommended for this purpose; namely, *Makers of Science* by Ivor B. Hart,[28] *Heroes of the Scientific World* by Charles R. Gibson[29] and *Leading American Men of Science* by David Starr Jordan.[30]

Hart's *Makers of Science* is intended, the author says, to be more than a series of detached biographies. He has tried so to arrange and link the chapters, in their sequence, as to form a chronological record of some of the broader movements in the progress of the physical sciences. Beginning with Aristotle and the Alexandrian School,[31] he goes on with Roger Bacon; Copernicus,[32] the father of modern astronomy; Kepler, its first systematizer; Gilbert, first expounder of magnetism; Galileo, whom he regards as the founder of experimental science; Descartes,[33] the first algebraic geometer; Isaac Newton, discoverer of universal gravitation; Robert Boyle,[34] student of the atmosphere and of gases; Ampère, who found out the relation between magnetism and electricity; Sir Humphry Davy,[35] student of chemical electricity; Georg Simon Ohm,[36] who gave

[28] Ivor Blashka Hart (1889-). Author of *The Great Physicists* (1927); *The Mechanical Investigations of Leonardo da Vinci* (1925) and other scientific books.

[29] Charles R. Gibson (1870-). Author of many scientific and technical books.

[30] David Starr Jordan (1851-). An American naturalist, President of Leland Stanford Jr. University.

[31] Alexandrian School. The ancient philosophers who strongly showed the influence of the teachings of the scholars of Alexandria in Egypt.

[32] Nicholaus Copernicus (1473-1543). A Polish astronomer who advanced the theory that the earth and the planets revolve around the sun.

[33] René Descartes (1596-1650). A French philosopher who exerted great influence on scientific thought.

[34] Robert Boyle (1627-1691). A British chemist.

[35] Sir Humphry Davy (1778-1829). An English chemist, inventor of the safety lamp for miners.

[36] Georg Simon Ohm (1787-1854). A German physicist who investigated galvanism.

his name to the law of electrical resistance; Michael Faraday,[37] whose work in electro-magnetic induction paved the way for the dynamo; and ends with Sir William Thomson,[38] pathfinder in the realms of heat and electricity, whose work in connection with ocean telegraphy won him a peerage with the title of Lord Kelvin.

Gibson gives to his book, *Heroes of the Scientific World,* the subtitle "An account of the lives, sacrifices, successes and failures of some of the greatest scientists in the world's history." The biographies duplicate in part those of Hart's collection, but they are written from a different point of view and the author gives us, in addition, accounts of Tycho Brahé,[39] who began as an astrologer and ended by making astronomy an exact science; of Benjamin Franklin,[40] our American sage who "snatched the thunderbolt from heaven"; of Dr. Joseph Priestley, discoverer of oxygen; of Henry Cavendish,[41] the eccentric English millionaire chemist; of the Herschels,[42] great English astronomers; of Dalton, the father of scientific chemistry; of Charles Darwin,[43] author of the theory of development by natural selection; and of Clerk-Maxwell who deduced mathematically the existence of the electro-magnetic waves used in radio, later found experimentally by Hertz.

These books are English and naturally lay stress on English work and workers. For a full treatment of recent French or

[37] Michael Faraday (1791-1867). An English physicist and chemist.
[38] Sir William Thomson (Lord Kelvin) (1824-1907). A British physicist.
[39] Tycho Brahé (1546-1601). A Danish astronomer.
[40] Benjamin Franklin (1706-1790). An American philosopher who, in 1752, proved that lightning is an electrical discharge.
[41] Henry Cavendish (1731-1810). An English chemist who discovered nitric acid.
[42] Sir William Herschel (1738-1822), and his son, Sir John Herschel (1792-1871). English astronomers of German descent. In 1781 Sir William discovered the planet Uranus.
[43] Charles Darwin (1809-1882). An English naturalist.

German scientists it would be necessary to go to works in those languages. Even our own men are somewhat neglected; but fortunately the third book, edited by President Jordan of Leland Stanford University, supplies this lack. Dr. Jordan's book is devoted to accounts of Benjamin Thompson, afterwards Count Rumford;[44] Audubon,[45] the great ornithologist; Benjamin Silliman,[46] chemist and founder of the *American Journal of Science;* Joseph Henry,[47] who first demonstrated the possibility of the electric telegraph; Louis Agassiz,[48] who introduced scientific zoölogy into this country from Europe; Jeffries Wyman,[49] anatomist, and Asa Gray,[50] botanist; James Dwight Dana,[51] who made "geology one of the departments of abstract science"; Spencer F. Baird,[52] of the Smithsonian Institution; O. C. Marsh,[53] who first explored the fossil-beds of the great West; Edward D. Cope,[54] chief upholder in this country of Lamarck's,[55] rather than Darwin's, views of devel-

[44] Benjamin Thompson (1753-1814). An American scientist, who set forward the theory that heat is a mode of motion. Having left America and taken an administrative office in Bavaria he became a Count of the Holy Roman Empire.

[45] John James Audubon (1780-1851). An American naturalist of French descent. His book, *Birds of America,* sold for $1,000 a copy.

[46] Benjamin Silliman (1816-1885). An American chemist.

[47] Joseph Henry (1797-1878). An American physicist, an investigator of electricity.

[48] Louis Jean Agassiz (1807-1873). An American naturalist of Swiss descent.

[49] Jeffries Wyman (1814-1874). An American comparative anatomist.

[50] Asa Gray (1810-1888). An American botanist, Professor of Natural History in Harvard University.

[51] James Dwight Dana (1813-1845). An American geologist, Professor of Geology in Yale University.

[52] Spencer F. Baird (1823-1887). An American naturalist.

[53] Othniel C. Marsh (1831-1899). An American geologist, noted for his study of fossils. Professor in Yale University.

[54] Edward D. Cope (1840-1897). An American biologist, Professor of Geology in the University of Pennsylvania.

[55] Jean Baptiste Lamarck (1744-1829). A French naturalist.

opment; Josiah Willard Gibbs, one of the world's greatest mathematical physicists; George Brown Goode [56] and William Keith Brooks,[57] zoölogists; and Henry A. Rowland,[58] inventor of the concave spectroscopic grating.[59] In this collection the biological sciences seem a little overweighted, probably because one of these, ichthyology,[60] was the specialty of the author. The book shows clearly, however, how great eminence in pure science has been European rather than American. Until recently our triumphs, if we except the case of Willard Gibbs, have been in invention rather than in research.

7. DARWIN, PASTEUR, CURIE, PUPIN

We may now take up a few books about individuals, selecting these for their readableness and avoiding those that are mere compendiums of fact.

First we may place Gamaliel Bradford's [61] life of Charles Darwin. It is odd how so much modern controversy—not between religion and science, but rather between certain religious men and certain scientific men—should have concentrated about the idea of organic evolution and about the person of one of the gentlest and least pugnacious of scientific investigators. Certainly Darwin did not originate the idea of a developmental series of organic beings. Such an idea is old in science and philosophy. And probably very few Christian believers who

[56] George Brown Goode (1851-1896). An American naturalist who made important studies of fish life.

[57] William Keith Brooks (1848-1908). An American biologist, Professor of Zoölogy in Johns Hopkins University.

[58] Henry A. Rowland (1848-1901). An American physicist, Professor of Physics in Johns Hopkins University.

[59] Concave spectroscopic grating. A grating made by ruling 10,000 to 40,000 parallel lines to the inch on glass or highly polished metal. The invention of this greatly improved the spectroscope.

[60] Ichthyology. The branch of zoölogy that concerns fish.

[61] Gamaliel Bradford (1863-). An American biographer.

have really thought about the first chapter of Genesis have failed to wonder about the methods and processes of creation, of which it gives no hint. That those must have been processes of development, one form from another, many thinkers before Darwin had concluded. Darwin's contribution was a theory that explained—or partly so—the way in which such development might have taken place. His greatest predecessor, Lamarck, believed that it was brought about entirely through the influence of surroundings and the immediate inheritance of the result of such influence. Some biologists still insist upon this. But it was Darwin's belief that it operated through what he called "natural selection," acting by "the survival of the fittest." The life of plants and animals, as he viewed it, was a continual "struggle for existence." Offspring resembled their parents, through heredity, but they always varied slightly. If these variations were favorable to survival in the struggle, those who bore them were preserved and passed them on to the next generation. Others were destroyed, and so the course of development went on.

Darwin's main theses are still held by the majority of biologists, with certain modifications. He did not attempt to explain variation but merely accepted it as an established fact. The theory of "pangenesis" [62] by which he attempted to explain heredity is no longer held. Much has since been done to clear up these matters. Darwin's service to science and to the explanation of the creative process in nature was that his was the first simple, clean-cut statement of a major developmental method. He did not attempt to connect it in any way with theological dogmas and it is the irony of fate that his name

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[62] Pangenesis. The theory that hereditary qualities are transmitted from the body cells to the germ cells.

should be regarded by some as that of an enemy of Christianity.

Darwin's *Life and Letters* in four volumes, edited by his son Francis,[63] is the authoritative source of information regarding him. *The Evolution of Charles Darwin* by Dr. George A. Dorsey,[64] author of *Why We Behave Like Human Beings,* is very adequate though emphasizing controversial aspects. The most recent treatment is Henshaw Ward's [65] excellent *Charles Darwin, the Man and His Warfare,* which has rather more detail; and there is also a good short life by Leonard Huxley.[66] It is recommended here that the reader begin with Gamaliel Bradford's *Darwin.* This is not by a scientific man, but it is by a skilled and experienced writer of biography, perhaps the best that we have in this country. He treats his subject topically, looking upon Darwin successively as the observer, the thinker, the discoverer, etc., with a final chapter on "The scientific spirit." Darwin's career lends itself well to this form of exposition, and Bradford's treatment, always felicitous, makes the book fascinating to those who agree with him and those who do not.

Next we may read of a Frenchman, and one of the greatest, whose career has some of the picturesqueness and adventure in which, as already noted, the lives of scientific men are often lacking. Louis Pasteur,[67] beginning his scientific work as a chemist and crystallographer,[68] found himself drawn by fate

[63] Francis Darwin (1848-1925). An English botanist.

[64] Dr. George A. Dorsey (1868-). An American anthropologist, or student of man in his various relations.

[65] Henshaw Ward (1872-). Author of many scientific and technical books.

[66] Leonard Huxley (1860-). An English editor and biographer.

[67] Louis Pasteur (1822-1895). A French chemist and bacteriologist, who began inoculation for hydrophobia.

[68] Crystallographer. A student of crystals.

into the realm of biology—a new biology, whose facts he ascertained and whose laws he deduced—that of extremely small organisms, part of it embracing what is known to us as bacteriology. "Among the researches that have made the name of Pasteur a household word," says Dr. William Osler,[69] "three are of the first importance—a knowledge of the true nature of processes in fermentation, a knowledge of the chief maladies which have scourged men and animals, a knowledge of the measures by which either the body may be protected against these diseases, or the poison neutralized."

The life of this man by René Vallery-Radot,[70] written originally in French, is available to readers of English in translation by Mrs. R. L. Devonshire.[71] To paraphrase a passage in Dr. Osler's introduction: "This is for young men of science, and for others who wish to know what science has done, and may do, for humanity. From it may be gleaned three lessons, (1) the value of method, of technique, in the hands of a great master, (2) the example of a man devoted to his friends, just and generous to his rivals, and patient under contradiction and opposition, and (3) humility before the unsolved problems of the universe."

The author of this book, René Vallery-Radot (1853–) was Pasteur's son-in-law and collaborator. He wrote in 1883, with his father-in-law's approval, a book entitled *The Story of a Scientist by an Ignoramus,* translated by Lady Claud Hamil-

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[69] Sir William Osler (1849-1919). A British physician, the author of many medical books.

[70] René Vallery-Radot (1853-). A French scientist, the son-in-law of Louis Pasteur.

[71] Mrs. R. L. [Henriette C.] Devonshire. Author of *Rambles in Cairo* (1917), *Some Cairo Mosques and Their Founders* (1921) and translator of important biographical works originally written in French (1902-1914).

ton [72] as *Louis Pasteur, His Life and Labors.* The present work was written after Pasteur's death, and is more complete than the earlier account.

The next book on our list is quite unique—the life of a professor by his wife, who, together with him, after a long and difficult research, brought to light the most remarkable of the chemical elements, radium. This couple, the Curies, the husband a Frenchman, the wife a Pole, Marie Sklodowska, gave to the world a wonderful demonstration of both the domestic and scientific virtues, rearing a family of children on an income representing the barest necessities while pursuing an investigation yielding finally a substance now valued at seventy thousand dollars a gram, without profiting personally by their work to the value of a sou. The world-wide honors that came to Madame Curie too late for her husband to share them (for his valuable life was cut short by a speeding motor-car) are fresh in the memories of all. This book, a tribute both of affection and of scientific admiration to one who was at once husband and collaborator, has elements of nobility of character and simple pathos that have rarely, if ever, been surpassed in literature.

Next we may take up a notable autobiography, that of Michael Pupin.[73] The scientific man is in the same class with the painter, the sculptor, the poet, the musical composer; he does his work from choice. He cannot help it; something impels him. Rarely does one of them set out with the fixed idea that he will follow science. He begins in some occupation where chance, or environment, or the decision of his parents,

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[72] Lady Claud Hamilton [Lady Elizabeth Emma Proby] (1821-1900). A translator of works from the French.

[73] Michael Pupin (1858-). An American physicist of Serbian origin, Professor of Electro-Mechanics in Columbia University.

has placed him. But sooner or later the "divine curiosity" gets the upper hand, and if it is strong enough, it finally monopolizes his life.

A Serbian peasant boy, living on the Austrian military frontier, would not seem a promising candidate for the post of a great electro-mechanical expert in a country thousands of miles away, with alien traditions and an unknown tongue. Michael Pupin's own account of how it all came about, in his book *From Immigrant to Inventor,* is a fascinating one; for his perfect mastery of his adopted language is by no means the least of his achievements. Landing in America as a penniless, friendless boy, he won the liking and respect of those he met, and his progress upward from farm-hand through factory worker to student and scientific investigator throws a most interesting light upon the methods of scientific research and the peculiar mental endowment that fits one for it.

No list of this sort would be complete without a reference to the man, still living, whose theories, now widely accepted, have unsettled the ideas of all scientific men regarding such fundamental elements of our thinking as space, time and force. The personality of Albert Einstein,[74] author of the famous Theory of Relativity, which regards time as a fourth dimension of space, gravitation as due to "kinks" in space near material bodies, and the "all-pervading" ether as non-existent, has been little touched upon in literature. There is no biography, but *Einstein the Searcher* by Alexander Moszkowski[75] contains a final chapter on "Einstein's life and personality" which is worth reading even if the rest of the book should remain unread. The whole, however, is based on conversations with the man him-

[74] Albert Einstein (1879-). A German-Swiss physicist.

[75] Alexander Moszkowski (1851-). A German writer, author of *Einstein the Searcher* (1921) and *The Isles of Wisdom* (1925).

self and should be found interesting by the general reader, with a little judicious skipping of technical matter.

The reader who has been stimulated, and whose interest and curiosity have been aroused by the reading outlined above, will want to follow it up, no doubt, with some of the longer works that have been named here and there, and with others unmentioned but available on the shelves of any good library. Those who have not the time to master the technical tools and methods of the sciences may, in this day of popularization, gain pleasure and profit in reading about them and about the men and women who have devoted their lives to untangling the riddle of the world as it is and to making for us and our children a new and better one.

WORK FOR CLASSROOM DISCUSSION OR FOR WRITTEN REPORTS

1 Popular Appreciation of Science

1 Explain the difference between pure science and applied science.
2 Why have laboratories multiplied?
3 What changed the American attitude towards science?
4 Why are the principles of science more fascinating than the applications?

2 The Scientist and the Inventor

5 Explain the different purposes of science.
6 How does a scientist differ from an inventor?
7 Why do inventors gain greater popularity than scientists?

3 Types of Discovery

8 What do scientists discover?
9 Present a series of illustrations to explain the different types of work accomplished by scientists.
10 How does science help us to understand the world in which we live?
11 How does science help to change the world in which we live?

4 Value of Scientific Knowledge

12 Explain the four uses to which scientific knowledge may be applied.
13 What great motive inspires scientists?
14 Why is the scientist, like the poet, "born, not made"?
15 What should be the training of one who wishes to discover new scientific truths?

5 Development of Scientific Thought

16 What method of work led to the great advance of science in modern times?
17 Explain the principal events in the development of scientific knowledge.
18 To what extent has science revealed the secrets of nature?

6 Short Biographies

19 Read from the books mentioned, or from an encyclopedia or other books of reference, and report interesting facts concerning the lives and works of certain great scientists.
20 In what type of scientific work have the people of the United States excelled?

7 Darwin, Pasteur, Curie, Pupin

21 Explain the expression, "A developmental series of organic beings."
22 Who originated the idea of a developmental series of organic beings?
23 Define the following scientific terms:
   (a) Natural selection
   (b) Survival of the fittest
   (c) The struggle for existence
   (d) Heredity
   (e) Variations
24 What did Charles Darwin accomplish?
25 What great contributions to scientific knowledge did Louis Pasteur make?
26 What three lessons may be learned from the life of Louis Pasteur?
27 Explain the term, "Divine curiosity."
28 Why are the lives of some scientists intensely interesting?
29 How may all people advance in scientific knowledge?

BOOKS FOR FURTHER READING

Makers of Science, Ivor B. Hart, *Oxford University Press,* 1923.
Heroes of the Scientific World (Former title, Heroes of Science), Charles R. Gibson, *Seeley, Service* (*Lippincott*), 1926.
Leading American Men of Science, David Starr Jordan, ed., *Holt,* 1910.
Charles Darwin, Gamaliel Bradford, *Houghton,* 1926.
The Life of Pasteur, René Vallery-Radot, *Doubleday, Page,* 1927.
Pierre Curie, Marie Sklodowska Curie, *Macmillan,* 1923.
From Immigrant to Inventor, Michael Pupin, *Scribner* (New Popular Edition), 1923.

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